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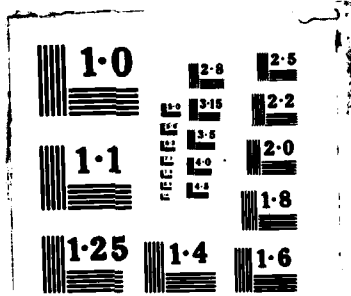
UNDERWATER FACILITIES INSPECTIONS AND ASSESSMENTS BY  
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**AD-A168 496**

**UNDERWATER FACILITIES  
INSPECTION AND ASSESSMENT  
AT**

**MAGNETIC SILENCING FACILITIES  
NAVAL STATION  
CHARLESTON, SOUTH CAROLINA**

**FPO-1-84(39)**

**NOVEMBER 1984**

**PERFORMED FOR:**

**OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE  
CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C. 20374**

**UNDER:**

**CONTRACT N62477-83-D-0387  
TASK I**

**BY:**

**COLLINS ENGINEERS, INC.  
600 WEST JACKSON BOULEVARD  
CHICAGO, ILLINOIS 60606**

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In August, 1984, an underwater inspection was conducted of facilities of the  
Magnetic Silencing Facilities at Pier Yankee and Downtown (MSF) at Naval  
Station Charleston, located in Charleston, South Carolina. The purpose of the  
inspection was to assess the condition of the submerged portions of (Con't)

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structures at those facilities, and to determine the underwater as-built condition of some newly constructed facilities at Pier Yankee.

Each facility was inspected by a team of engineer- and technician-divers using visual, tactile and non-destructive testing techniques. A program of ultrasonic testing and coring was used to determine the condition of timber piles. The detailed inspection included cleaning and scraping of selected areas of the piles and documentation of conditions using color photographs. The verticality of exposed instrument sensing tubes were verified, exposed cable runs were visually inspected, and soundings were made of the channel bottom.

The newly constructed facilities at Pier Yankee are in excellent condition below water. A few areas of minor damage were noted above water. A few areas of minor damage were noted above water and are described in this report, but since construction was in progress at the time of the inspection it is assumed that correction of these deficiencies will be made by the contractor and no repair costs are included for those items.

The older facilities at Pier Yankee are generally in good condition below water. There are three areas of minor cracking and scaling on the prestressed concrete piles supporting the Stray Field Measurement Building that should be repaired to prevent further deterioration. The timber piles of the Boat House, the timber piles and bracing of the platform south of the Stray Field Measurement Building, and the timber piles supporting the tank below the Electrical Equipment Shelter have suffered damage from limnoria, marine borers, at the waterline, but their capacity has not significantly reduced and no repairs are recommended at this time.

The prestressed concrete piles supporting the building and pier structures at MSF Downtown are in excellent condition, and no repairs are recommended at this time. The timber piles and bracing of the mooring dolphin and platform dolphins at the downtown facility are in fair condition, having suffered surface damage at the waterline due to marine borer attack. The rock-filled crib is in fair condition with some minor holes that should be repaired to prevent the future loss of fill material. The sensor tubes and cables appear to be in good condition.

## EXECUTIVE SUMMARY

In August, 1984, an underwater inspection was conducted of facilities of the Magnetic Silencing Facilities at Pier Yankee and Downtown (MSF) at Naval Station Charleston, located in Charleston, South Carolina. The purpose of the inspection was to assess the condition of the submerged portions of structures at those facilities, and to determine the underwater as-built condition of some newly constructed facilities at Pier Yankee.

Each facility was inspected by a team of engineer- and technician-divers using visual, tactile and non-destructive testing techniques. A program of ultrasonic testing and coring was used to determine the condition of timber piles. The detailed inspection included cleaning and scraping of selected areas of the piles and documentation of conditions using color photographs. The verticality of exposed instrument sensing tubes was verified, exposed cable runs were visually inspected, and soundings were made of the channel bottom.

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The older facilities at Pier Yankee are generally in good condition below water. There are three areas of minor cracking and scaling on the prestressed concrete piles supporting the Stray Field Measurement Building that should be repaired to prevent further deterioration. The timber piles of the Boat House, the timber piles and bracing of the platform south of the Stray Field Measurement Building, and the timber piles supporting the tank below the Electrical Equipment Shelter have suffered damage from limnoria, marine borers, at the waterline, but their capacity has not been significantly reduced and no repairs are recommended at this time.

The prestressed concrete piles supporting the building and pier structures at MSF Downtown are in excellent condition, and no repairs are recommended at this time. The timber piles and bracing of the mooring dolphin and platform dolphins at the downtown facility are in fair condition, having suffered surface damage at the waterline due to marine borer attack. The rock-filled crib is in fair condition with some minor holes that should be repaired to prevent the future loss of fill material. The sensor tubes and cables appear to be in good condition.

The table on the following page summarizes the condition of each facility and recommended repairs with associated estimated costs.

# UNDERWATER FACILITIES INSPECTION AND ASSESSMENT

AT

## MAGNETIC SILENCING FACILITIES

### NAVAL STATION

CHARLESTON, SOUTH CAROLINA

Facility	Year Built/ Reconstructed	No. of Piles	Facility Size Length by Width	Structure Type	Recommendations*	Estimated Cost of Recommendations
Pier Yankee:						
Access Pier	1984	75	1,120'-0" x 12'-0"	14" square prestressed concrete piles	Repair pile cap at Bent 73; repair 2 piles at Bent 80	Contractor's responsibility (\$1,000)
Turnaround Area	1984	10	40'-0" x 42'-0"	14" square prestressed concrete piles	No Repairs	
Timber Walkway	1984	48	424'-0" x 6'-0"	14" Timber piles	No Repairs	
Finger Pier 1	1984	127	208'-0" x 14'-0"	14" Timber piles	No Repairs	
Finger Pier 2	1984	127	208'-0" x 14'-0"	14" Timber piles	Repair bracing at Bent 23	Contractor's responsibility (\$1,000)
Stray Field Measurement Building	1965/1981	43	52'-0" x 68'-7"	18" square prestressed concrete piles & Timber piles	Repair piles 1A, 1C, & 31 with epoxy grout.....	\$12,000
Boat House	1965	28	72'-0" x 24'-0"	12" Timber piles	No Repairs	
Bulkhead	1984	498	606 linear feet	14" Timber piles	No Repairs	
Range Marker Pile	Unknown	1	--	Timber pile	No Repairs	
3 Mooring Dolphins	1984	107	—	14" Timber piles	No Repairs	

\* Reinspect timber piles at 3 year intervals until limnoria attack is assessed as not progressing significantly; reinspect other facilities at 6 year intervals.

# UNDERWATER FACILITIES INSPECTION AND ASSESSMENT

AT

## MAGNETIC SILENCING FACILITIES

### NAVAL STATION

CHARLESTON, SOUTH CAROLINA

Facility	Year Built/ Reconstructed	No. of Piles	Facility Size Length by Width	Structure Type	Recommendations**	Estimated Cost of Recommendations
<u>Magnetic Silencing Facility - Downtown</u>						
Pier and Building	1961	56	116'-0" x 9'-0"	14" square prestressed concrete piles	No Repairs	
Pendering System	1961	7	50 linear feet	Timber piles	Replace pile system....	\$50,000
Rock Crib	1969	—	63'-0" x 11'-0"	Rock-filled timber crib	Repair holes in sheeting with grout- filled bags.....	\$25,000
Instrument Sensor Tubes	Various, Unknown	--	63 tubes	--	No Repairs	
Platform Dolphin 1	Unknown	7	15'± x 6'-0"	Timber and prestressed concrete piles	Repair concrete pile cap with formed concrete; jacket timber piles with concrete and replace bracing...	\$30,000
Platform Dolphins 2-5	Unknown	16	6'-0" x 6'-0"	Timber piles	Jacket piles with concrete and replace bracing.....	\$50,000
Mooring Dolphin	Unknown	3	--	Timber piles	Replace dolphin.....	\$25,000

\*\* Reinspect timber piles at 3 year intervals until repaired;  
reinspect after repairs; and reinspect at 6 year intervals thereafter.



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UNDERWATER FACILITIES  
INSPECTION AND ASSESSMENT  
AT  
MAGNETIC SILENCING FACILITIES  
NAVAL STATION  
CHARLESTON, SOUTH CAROLINA

1. INTRODUCTION

This report consists of the results of a detailed underwater and above water inspection and assessment of submerged and above water portions of piles, pile caps, cable runs, and instrument tubes of facilities at Pier Yankee and MSF Downtown at Naval Station Charleston in Charleston, South Carolina.

The investigation was conducted by Collins Engineers, Inc. for the Ocean Engineering and Construction Project Office (FPO-1) of the Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) as Part II of Task No. 1 of Contract N62477-83-D-0387 as part of NAVFAC's Specialized Inspection Program. The Specialized Inspection Program sponsors task-oriented engineering services for the inspection, analysis, and design and monitoring of repairs for the submerged portions of selected Naval waterfront facilities.

1.1 Task Description

This part of the task consisted of furnishing the engineering services necessary to achieve an assessment of the apparent general condition of piles supporting structures, dolphin piles, bulkhead piles, instrument tubes, cable runs, and a rock-filled timber crib at the magnetic silencing facilities. This part of the task consisted of two phases: a field investigation phase and an assessment phase.

The field investigation phase consisted of an underwater inspection of submerged pilings and other elements by an engineer-diver and two technician-divers, and an above water inspection of the members near the waterline. The inspections were conducted in such detail as to permit a general assessment of the physical condition of the portions of the substructure that are submerged or subject to frequent wetting by wave or tidal action. Some of the facilities at Pier Yankee were recently

constructed, and an additional purpose for inspecting those facilities was to establish a baseline against which to judge the results of future inspections. A visual "swim-by" survey was made of all facilities under investigation, and a more detailed visual and tactile inspection was made of selected facility components. This detailed inspection included scraping and cleaning, and measurement of the components.

A total inspection included three levels of effort, employed as phases. Each facility/structural element was inspected in one, two, or three of these phases (Levels I, II, and III) as considered necessary for adequate condition assessments and are delineated in Paragraph 3.1. These inspection phases, or levels of effort, were performed in accordance with the CHESNAVFACENGCOM scope of work definitions indicated below:

Inspection Phase  
Level I:

General Inspection: This inspection phase is essentially a "swim-by" overview, which does not involve cleaning of any structural elements, and therefore can be conducted much more rapidly than the other levels of inspection. The Level I survey should confirm as-built structural plans and detect obvious major damage or deterioration due to overstress (collisions, ice), severe corrosion, or extensive biological attack. The underwater inspector shall generally rely primarily on visual and tactile observations to make condition assessments. Visual documentation (utilizing underwater television and/or photography) may be included with the quantity and quality adequate for documentation of the findings which will be representative of the facility condition.

Inspection Phase  
Level II:

Detailed Inspection: This phase of the inspection will often require prior cleaning of the structural elements. The purpose of the Level II effort is to detect surface damage which may be hidden by marine growth and/or deteriorated surface material. Generally, cleaning is time-consuming, and therefore restricted to areas that are critical or which may be representative of the entire structure itself. The amount and thoroughness of cleaning to be performed is governed by what is necessary to discern the exterior physical condition of the structural members, and to rapidly obtain nominal measurements by means of simple instruments such as calipers, measuring tapes, and ice picks. This inspection phase should identify areas that have been mechanically damaged or are in advanced states of deterioration.

Visual documentation (utilizing underwater television and/or photography) and a sampling of physical measurements should be included with the quantity and quality adequate for documentation of the findings which will be representative of the facility condition.

Inspection Phase  
Level III:

Highly Detailed: This inspection phase will often require the use of Non-Destructive Testing (NDT) techniques. It may also require the use of partially destructive techniques such as sample coring through wood structures, physical material sampling, or in-situ surface hardness testing. This phase will usually require prior cleaning of the structure. The use of NDT techniques generally concentrates on key structural areas, suspect areas, and structural members most representative of the underwater structure. Underwater television and/or photography showing examples of the facility's condition may be included.

The assessment phase of the investigation consisted of documenting the configuration of the existing structures; summarizing the conditions encountered during the field inspection; evaluating their structural and functional significance; and recommending actions that should be taken to insure long-term, cost-effective maintenance and utilization of the facilities. Estimated costs for repairs were also developed.

1.2 Report Content

The report contains a description of the Naval Station and its facilities including location; mission; and environmental data describing climatic, topographic, and hydrologic features along with a discussion of the inspection procedures. The report also contains the results of the inspection and an assessment of the findings, accompanied by pertinent drawings and photographs. The inspection results include a description of the structural configuration of the facilities along with their apparent condition and an assessment of the conditions found. Recommendations including cost estimates for any repair or maintenance work are also included.

## 2. ACTIVITY DESCRIPTION

### 2.1 Name of Activity

Naval Station Charleston, South Carolina.

### 2.2 Location of Activity

The Naval Station is located near the Atlantic seaboard approximately ten miles north of the City of Charleston, South Carolina, in Charleston County. It is contained within the Naval Base South area of the Charleston Naval Complex and covers 1,150 acres. The station lies on the west bank of the Cooper River, beginning approximately ten miles upriver from the mouth of Charleston Harbor and continuing upstream for about 2 miles. Magnetic Silencing Facilities (MSF) Downtown are also located in downtown Charleston on the west bank of the Cooper River near its confluence with the Ashley River in Charleston Harbor. (Figures 1, 2 and 3).

### 2.3 Mission of Facility

The mission of the Naval Station Charleston is: "To provide, as appropriate, logistic support for the operating forces of the Navy, and for dependent activities and other commands as assigned. Some of the services provided are as follows:

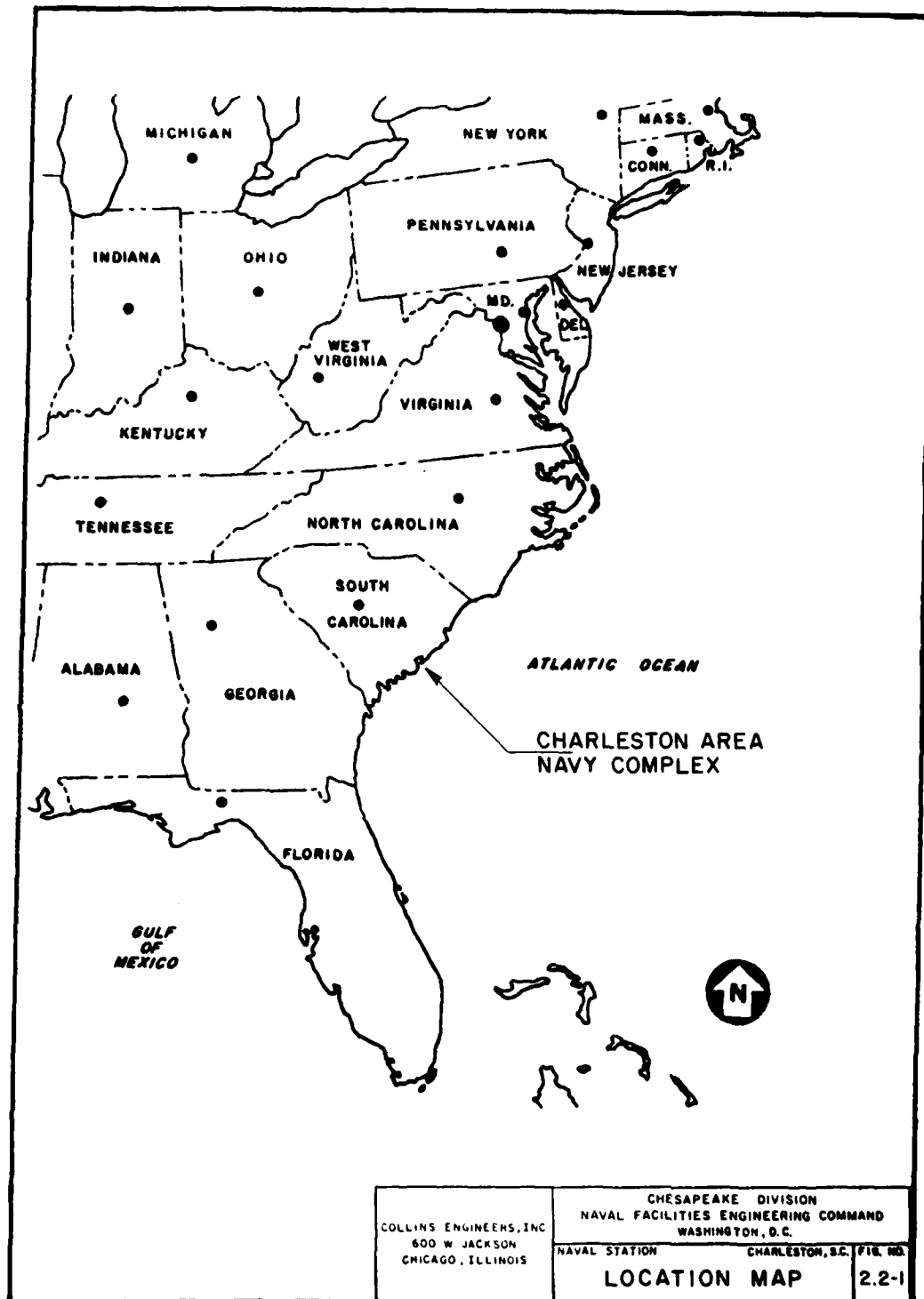
Port services, including berthing, tugs, pilots, cranes, fueling, literage, sludge removal for pollution control, and ammunition handling services. Twenty boats are assigned to this department, and pilots are involved in about 4,000 ship movements annually".

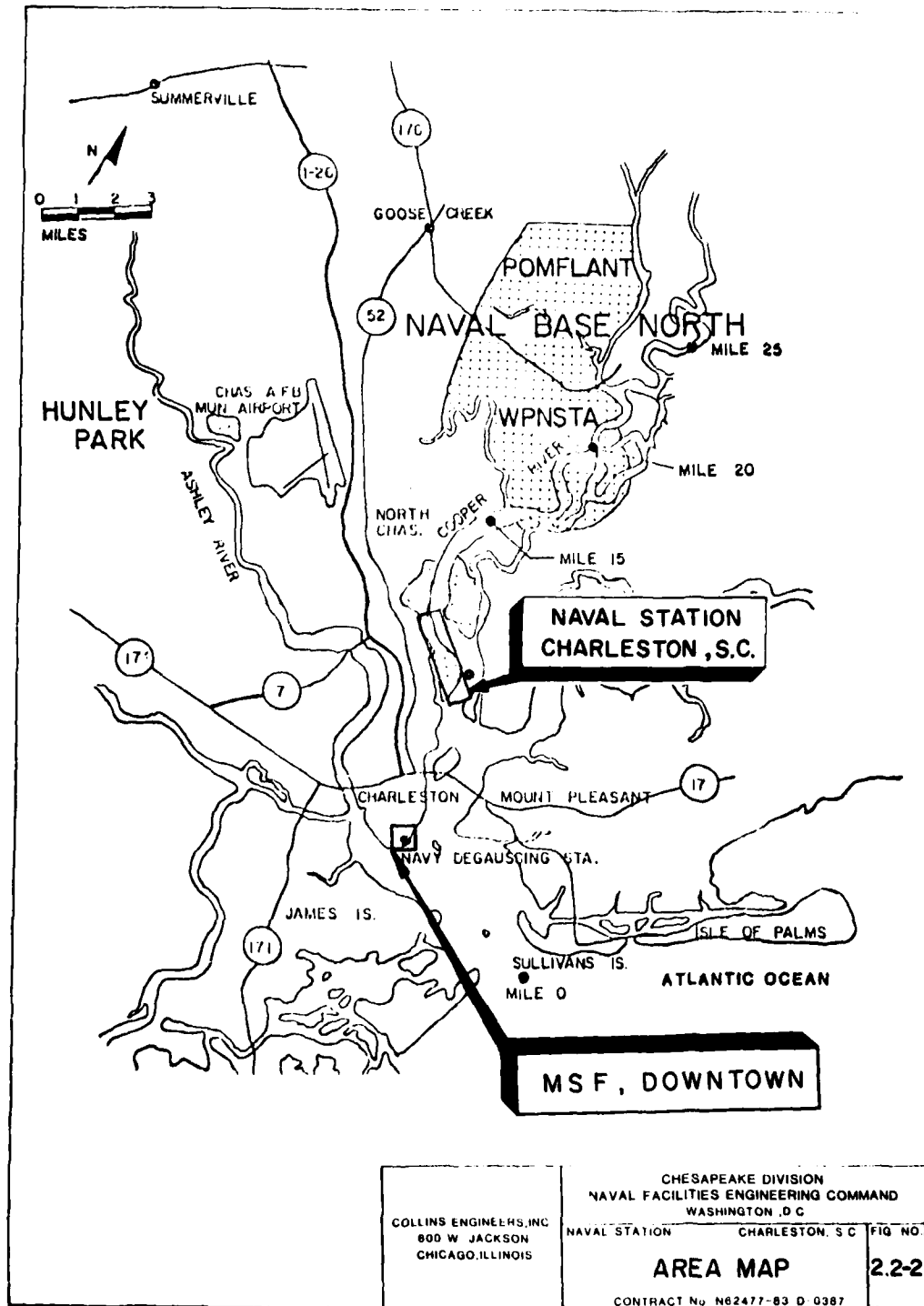
### 2.4 Description of Activity

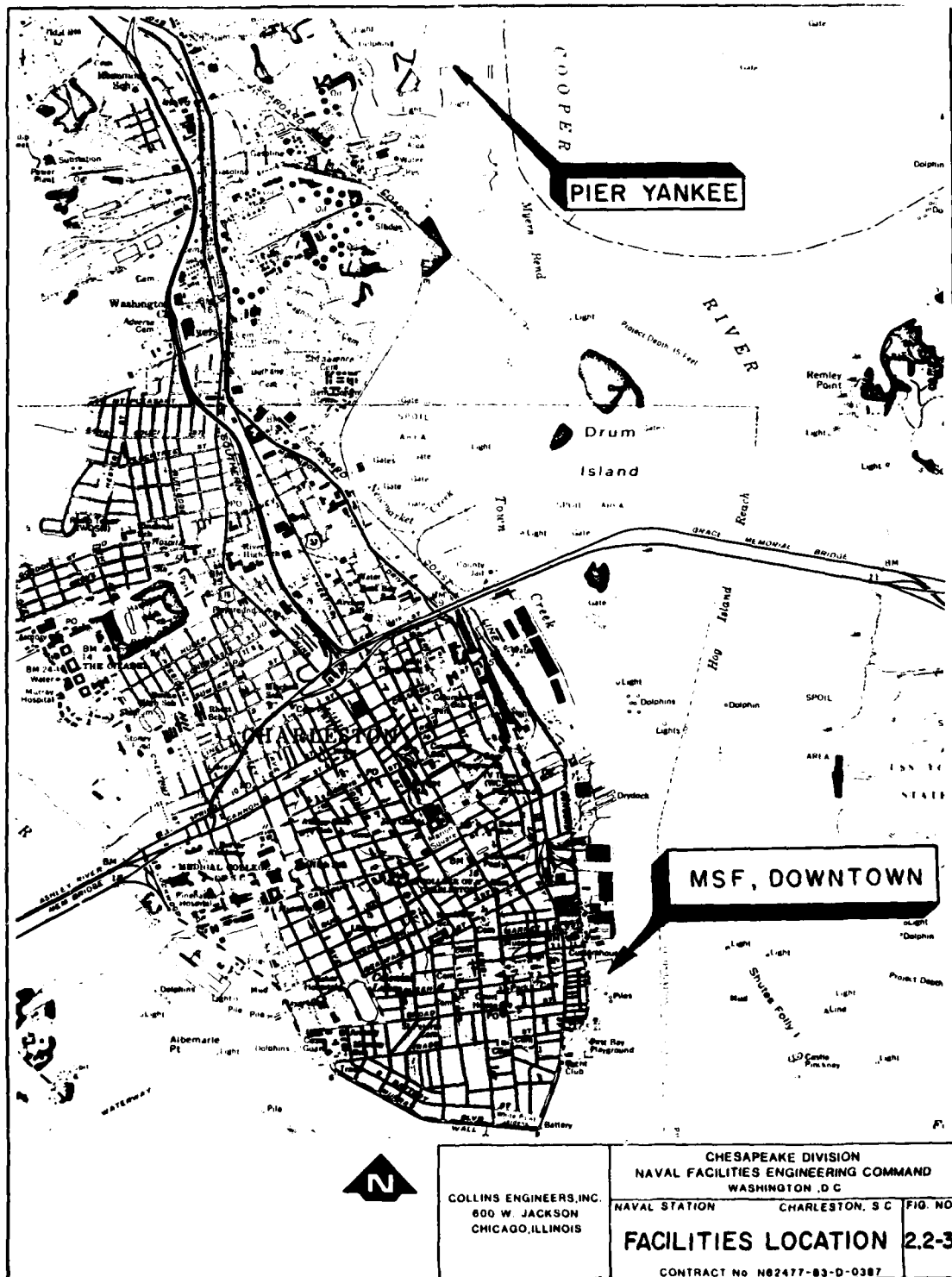
This report is concerned with waterfront magnetic silencing facilities located at the Naval Station and downtown Charleston. The table below identifies the principal features of the facilities which are the subject of this report:

<u>Facility</u>	<u>Year Built</u>	<u>Dimensions</u>
Pier Yankee:		
Access Pier	1984	1,120 ft x 12 ft
Turnaround Area	1984	40 ft x 42 ft
Walkway	1984	424 ft x 6 ft
Finger Pier 1	1984	208 ft x 14 ft
Finger Pier 2	1984	208 ft x 14 ft
Stray Field		
Measurement Bldg.	1965 & 1981	52 ft x 69 ft
Boat House	1965	72 ft x 24 ft
Bulkhead	1984	606 linear ft
Range Marker Pile	Unknown	1 pile
Mooring Dolphins	1984	Two 19-pile One 29-pile









MSF-Downtown.

Piers & Building	1961	117 ft x 9 ft
Fendering System	1961	50 linear ft
Rock Crib	1969	63 ft x 11 ft
Instrument Sensor Tubes	Various	24
Platform Dolphin 1	Unknown	15 ft x 6 ft
Platform Dolphins 2-5	Unknown	6 ft x 6 ft
Mooring Dolphin	Unknown	3 piles

## 2.5 Environmental Data

### 2.5.1 Climate

"In general the climate of the area is temperate, modified considerably by the nearness of the ocean. Monthly wind speeds average 9 mph with wind directions varying with the season. The area is subject to occasional hurricanes between July and September.

The area experiences no dry seasons although nearly 41% of the 49 inches of average annual precipitation occurs during the summer months. Thunderstorms are most frequent during the summer".

Mean monthly precipitation ranges from a low of 2 inches to a high of 7.5 inches. Relative humidity ranges from an annual low of 57% to a high of 87%. Annual records indicate that the sky is sunny an average of 64% of the daylight hours.

"The annual temperature ranges from 55 degrees to 75 degrees F. with a mean of 64 degrees F. Summer temperatures (June to August) range from 70 to 90 degrees F. with an average of 80 degrees F., while winter temperatures (December to January) range from 37 degrees to 57 degrees F. with an average of 47 degrees F.

### 2.5.2 Topography and Hydrology

"The Charleston Navy Complex is located in an area of very level topography. The maximum elevation of this area is approximately 35 feet above mean sea level. This level topography along with the rainy, humid climate of the region, produces many low draining areas. Naval Base South tends to be swampy with little relief; on the other hand, Naval Base North has an abundance of fresh water ponds and extensive forests". Ground water is found from 2 to 18 feet beneath the surface.

"The basic flood used for Navy planning is the 100 Year Flood. This identifies an elevation that rising water is expected to reach once in every 100 years. The 100 year flood plain for the Charleston area is 10 feet above mean sea level. All buildings containing materials dangerous to the public, residential buildings, and buildings needing a high degree of protection must be sited above the 100 year flood plain".

Almost all the land within Naval Base South lies below the 100 year flood plain, making it nearly impossible to comply with this siting restriction. However, Naval Base North contains considerable usable area above the 100 year flood plain.

Although the Naval Station is located between 10 and 12 miles upstream from the mouth of Charleston Harbor, it is tidally influenced and is marine in character. Tidal ranges for the Naval Station are as follows:

Extreme High Water.....	+10.7 feet
Mean High Water.....	+ 5.1 feet
Mean Low Water.....	+ 0.0 feet
Extreme Low Water.....	- 2.7 feet

Datum is Mean Low Water.

The Naval Station requires regular dredging to remove the considerable amount of silt deposited by the river. The river channel is maintained at a depth of 35 feet below mean low water.

#### 2.5.3 Seismic Activity

"The Naval Station is located in Seismic Probability Zone 3, where major damage would be expected".

#### 2.6 Footnotes

1. Underwater Facilities Inspections and Assessment at Naval Station (NS) Charleston, S.C., FPO-1-81-(9); May, 1981, p. 2-1.
2. Charleston Naval Complex Master Plan, Southern Division, NAVFAC-EC, p. III-17.
3. Ibid., p. II-16.
4. Underwater Facilities Inspections and Assessment, p. 2-4.
5. Southern Division, NAVFAC-EN, p. IV-25.
6. Design Manual, Harbor and Coastal Facilities, NAVFAC DM-26, 1968, p. 26-1-6.
7. Seismic Design for Buildings, Technical Manual NAVFAC P-355, February, 1982, p. 3-19.

### 3. INSPECTION PROCEDURE

Between August 13 and 17, 1984, an underwater inspection of submerged portions of pilings, a rock crib, cable runs, and sensor tubes; and an above water inspection of the exposed portions of the piles and pile caps was performed by a team of engineer- and technician-divers of facilities of Pier Yankee at the Naval Station, Charleston, South Carolina, and of facilities at the Magnetic Silencing Facility, Downtown, Charleston, South Carolina. The inspection was conducted in such detail as to permit a general assessment of the physical condition of the portions of the facilities that are submerged or subject to frequent wetting by wave or tidal action.

The level of inspection and the types of components to be inspected required the selection of inspection tools and methods that were both effective and efficient. The techniques were selected to yield sufficient information to make a general assessment of the supporting structures of each facility, locate and identify the extent of areas of significant damage or deterioration; and estimate rates of deterioration.

#### 3.1 Level of Inspection

The extent of the inspections conducted at each facility was predetermined. Generally, a Level I inspection was conducted of all accessible underwater elements. Refer to Section 1.1 for definitions of the various levels of inspection. Refer to Section 2.4 for a detailed list of the facilities. A summary of the extent of the inspections conducted at each facility follows:

<u>Facility</u>	<u>Level I</u> <u>No.</u>	<u>Level II</u> <u>No.</u>	<u>Level III</u> <u>No.</u>	<u>Total in</u> <u>Facility</u>
Pier Yankee:				
Timber Piles	837	30	26	945
Concrete Piles	109	21		130
MSF Downtown:				
Concrete Piles	24	34		56
Timber Piles	7	23	21	30
Instrument Tubes	51	12		63
Cable Runs at-				
Medium Range	1			1
Shallow Range	1			1
Pierhead	1			1
Timber Crib	1			1

It should be noted with regard to the preceding summary that at the time of the inspection, new construction was in progress at Pier Yankee and not complete. The number of piles inspected is, therefore, less than the total number of piles in the completed facility.

The concrete piles selected for the Level II phase inspection were scraped and cleaned in a band at least 10 inches wide on three sides, at three heights: Mean Low Water (MLW), Mudline (ML) and halfway between MLW and ML. Likewise, the circular timber piles selected for the Level II phase inspection were cleaned all around at the same three heights. Where the water depth was less than about 9 feet, the cleaning of the middle band was eliminated. When the water depth was less than about 3 feet, only one band was cleaned.

Representative as well as unusual conditions observed during the various levels of inspection were documented with color photographs.

### 3.2 Inspection Procedure

A detailed underwater inspection was made of the accessible portions of the facilities described above. The inspection included bearing and batter piles made of wood and concrete. Generally, the inspection covered an area from the pile cap to the ML. Cable runs were followed where accessible and tubes which could be located were visually inspected.

The underwater inspection was conducted by a three person team, including one engineer-diver, and two technician-divers. The divers, using scuba equipment, worked from a small boat, from floating equipment moored to the facilities, or from the facility itself.

In making the inspections, at least two divers were in the water near each other. A tender/notetaker observed and coordinated the divers' work. The Level I survey done on timber and concrete piles generally consisted of the diver descending individual piles, circling around the piles while inspecting them. Upon reaching the bottom, the diver swam to the next pile and continued the inspection. The Level I survey for bulkhead type structures consisted of a pair of divers swimming along the face of the structure at various levels. The procedure was repeated as dictated by the visibility in water to ensure that the entire face of the structure was inspected. The Level I survey done on the sensor tubes consisted of examining the tubes for an I.D. tag, checking the existence of the caps and sensors, and also checking the cables to see that they were still joined to the tubes and platform piles.

The Level I survey of the rock crib consisted of a visual and tactile inspection of the timber side and top members of the structure, and determination of the level of the fill within the crib and the channel bottom adjacent to the crib.

The Level I survey of the cable runs consisted of visually and tactilely inspecting the cable runs, searching for evidence of surface damage. The divers followed the cables until they became buried in the channel bottom, and attempted to uncover them where possible to continue the inspection.

On the surface, the divers reported the general conditions encountered to the tender/notekeeper. If the divers encountered significant distress, deterioration, or any irregularity they would surface immediately and report their findings to the tender/notekeeper.

Selected elements of the facilities were given a more detailed visual and tactile inspection (Level II). The detailed inspection done on timber and concrete piles included cleaning and scraping, and sounding and probing as necessary to determine the condition of the pile. When defects, such as cracks, were discovered, the piles were cleaned at more than three locations in order to determine if the defect was continuous from MLW to ML. The detailed inspection done on the sensor tubes included the use of an inclinometer to measure the verticality of each tube within plus or minus one degree.

The diver scraped and cleaned representative areas to include Level II efforts during the Level I survey. Photography was completed at a later time.

The Level III phase inspection consisted of ultrasonic testing of timber piles of the Boat House at Pier Yankee and the Platform Dolphins and Mooring Dolphin at MSF Downtown. The ultrasonic testing was performed under the direction of Dr. M. S. Aggour. The testing technique employed is a wave propagation technique. The methodology was developed and the verification of the validity of the technique for this type of use was documented by the Civil Engineering Department of the University of Maryland under grants from the U.S. Department of Transportation, Federal Highway Administration and the Maryland Highway Administration. This non-destructive testing technique provides a quantitative method of measuring the in-place residual strength of timber pilings that have been immersed in water for long periods. The method recognizes the damage to the wood microstructure which can cause loss of strength and density. The method is also able to detect internal damage caused by marine borers. The divers ultrasonically tested the piles at the locations cleaned as part of the Level II phase inspection. Refer to the Appendix (A-1) for a detailed discussion of the ultrasonic testing program. Borings were also made of the piles at right angles with an air-operated drill motor and the interior of the piles probed with incremental wire gages to verify the ultrasonic testing.

The inspection team also used a recording type fathometer to determine the channel bottom elevation throughout the facilities. The instrument provided a continuous strip chart representation of the channel bottom. The fathometer was moved across the area to be inspected at a constant speed and the location of reference points was indicated on the strip chart by



an internal marking system and pen-and-ink notations made by the operator.

The condition of the pile caps was determined by the engineer working from a small boat. This inspection consisted of visual observations and notetaking.

Underwater photography, as well as detailed notes and sketches, was utilized to document the conditions encountered in the inspection. Also, an on-site report of the progress of the inspection was made on a daily basis to the on-site government representative.

### 3.3 Inspection Equipment

During the inspection, various pieces of equipment were used to accomplish different tasks. A continuous reading recording type fathometer was used to determine the channel bottom along each facility. Scrapers were used to clean the piles. A clear water box, a Nikonos IV-A underwater camera with various lenses and a Popular Aqua F1 strobe was used to document the inspection findings. Miscellaneous minor equipment included dive lights, knives, and spray paint.

On the timber piles, a pneumatic drill was used along with different drill bits for boring and coring during the Level III phase. The ultrasonic measurements were made using a low frequency pulse velocity meter, V-Meter, manufactured by James Instruments.

#### 4. FACILITY INSPECTED

Each group of facilities inspected at Pier Yankee and MSF Downtown of Naval Station Charleston are discussed in the following sections. The discussion of each group of facilities is presented in four parts:

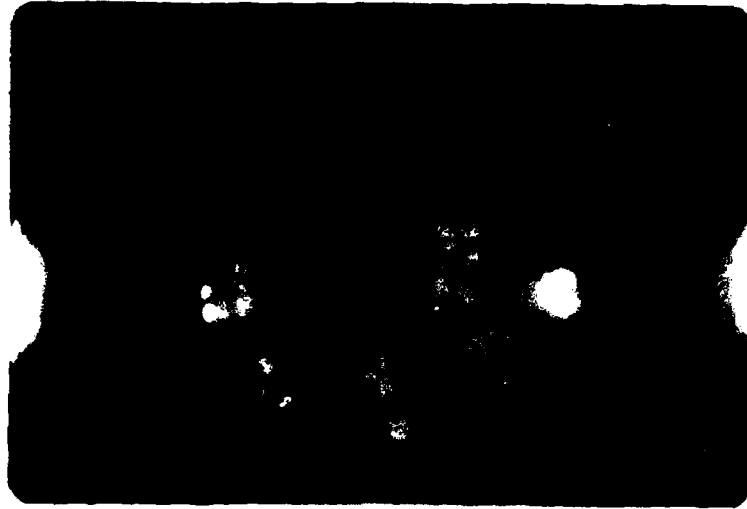
1. A description of the facilities,
2. A discussion of the conditions observed during the inspection,
3. An assessment of the conditions,
4. Recommendations to ensure long term serviceability.

In the sections which describe the configuration of each group of facilities, the figures included were developed from available drawings and inspection notes. Available design load data is summarized for the structures. These figures may be found on the pages immediately following the descriptive section. Their general conformance with actual field conditions was verified by visual observations and measurement.

The underwater visibility at the time of the inspection averaged less than two feet. All water depths described in the following sections are referred to Mean Low Water, Elevation 0.00.

Detailed breakdowns of the cost estimates for recommended repair and maintenance are included in the Appendix.

The marine growth on the structures at MSF Downtown generally consisted of 2 to 3 inches of tightly attached oysters and barnacles. At Pier Yankee, the marine growth observed on all but the newly constructed submerged structures consisted of 1 to 2 inches of tightly attached oysters and barnacles. All of the marine growth could be removed with difficulty by vigorous hand scraping. There was also evidence of marine borer, *Limnoria*, on all timber at both locations except at the newly constructed facilities, and the older concrete piles have been stained brown by the river water. Refer to Photograph 4.-1 for a typical example of marine growth at Pier Yankee, and refer to Photograph 4.-2 for a view of typical marine growth at MSF Downtown.



PHOTOGRAPH 4.-1 Typical Marine Growth at  
Pile E1, Stray Field Measurement  
Building, Pier Yankee.

PHOTOGRAPH 4.-2 Typical Marine Growth at  
Pile 16B, MSF Downtown.



#### 4.1 Pier Yankee

##### 4.1.1 Description

Pier Yankee is located on the east shore of the Cooper River near the southern end of Naval Station Charleston. Refer to Figure 2.2-3 for the location of the pier.

The Pier Yankee facility includes an access pier, turnaround area, timber walkway, two finger piers, the stray field measurement building, an electrical equipment shelter, a boat house, a timber bulkhead, and mooring dolphins. A range marker pile, associated with these facilities is located about one half mile upstream. The boat house and stray measurement building were constructed in 1965; the date of construction of the range marker pile is unknown; and the construction of the other facilities was being completed at the time of this inspection in August, 1984. Refer to Figures 4.1-1 through 4.1-6 for plans and typical details of the facilities.

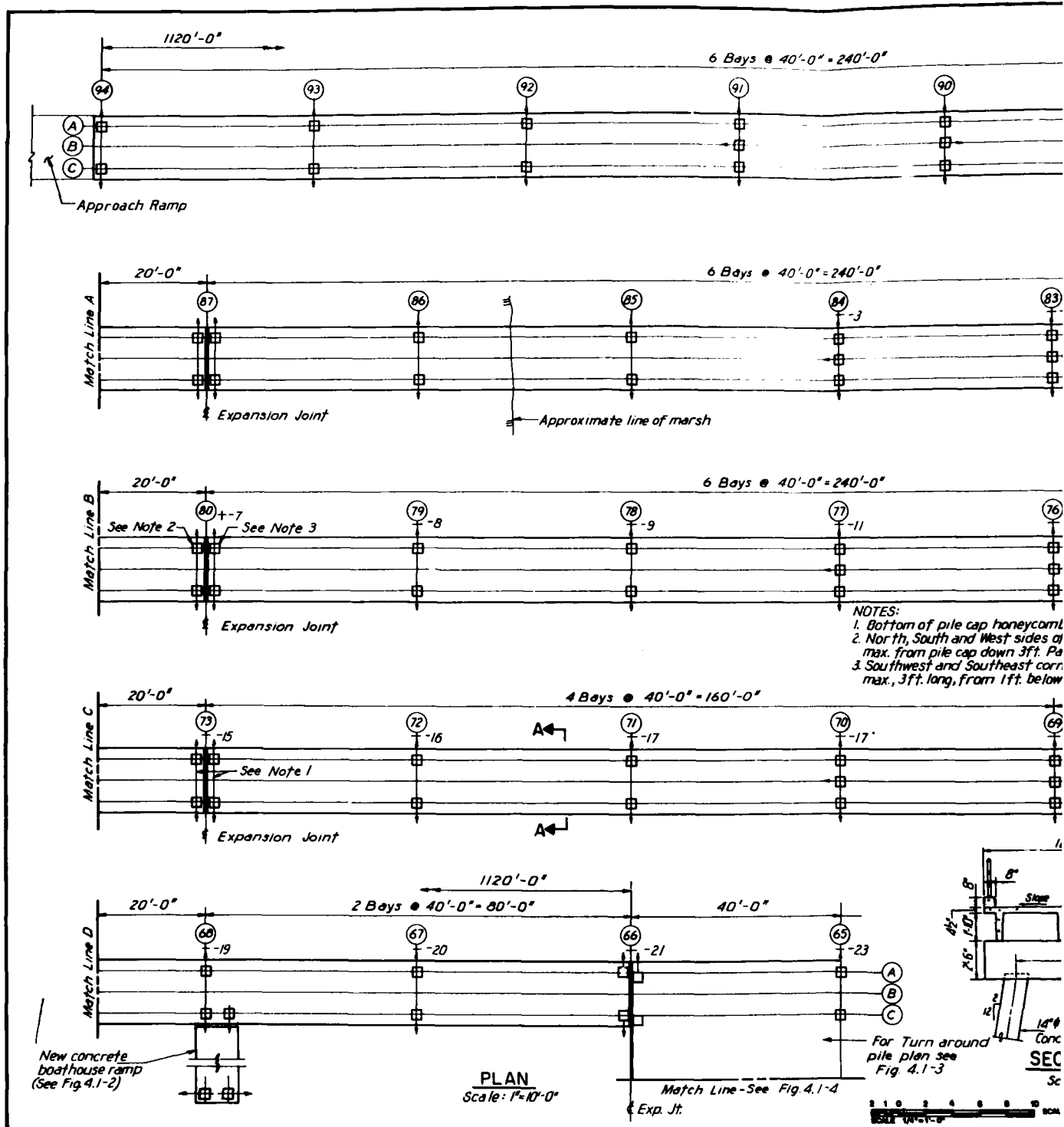
The access pier is a concrete structure approximately 1120 feet long by 12 feet wide extending from the shore to the turnaround area. The pier is constructed of 73 batter precast, prestressed concrete piles with cast-in-place concrete pile caps supporting a deck of precast, prestressed concrete double-T beams. The water depth along the access pier varies from zero near shore to about 21 feet near the outboard end. Refer to Figure 4.1-1 for a plan of the access area and a typical section showing the configuration of the structure. Refer to Photograph 4.1-1 for a view of the access pier.

There is a single span concrete structure connecting the access ramp to the boat house that is of construction similar to the access pier. The 41 feet long by 8 feet wide ramp is supported on the north end by piles of the access pier and on the south end by two batter precast, prestressed concrete piles. Refer to Figure 4.1-2 for a plan of the ramp and sections showing the configuration of the structure.

The boat house is a timber mill type building supported on 16 vertical and 10 batter timber piles. It is approximately 73 feet long by 24 feet wide. Two timber fender piles are located at the southern entrance to the boat house. The water depth near the boat house varies from approximately 20 feet at the north end to 26 feet at the south end. Refer to Figure 4.1-2 for a plan and a typical section showing the configuration of the structure. Refer to Photograph 4.1-2 for a view of the boat house.

The turnaround area is approximately 40 feet by 42 feet and is constructed on 6 vertical and 4 batter precast, prestressed concrete piles with two cast-in-place concrete pile caps supporting a deck of precast, prestressed concrete double-T beams. The water depth around the turnaround area varies from about 21 to 26 feet. Refer to Figure 4.1-3 for a plan of the turnaround area, and a typical section showing the configuration of the structure.

The stray field measurement building is a masonry



6 Bays @ 40'-0" = 240'-0"

20'-0"



6 Bays @ 40'-0" = 240'-0"

20'-0"

Match Line B

6 Bays @ 40'-0" = 240'-0"

20'-0"

Match Line C

**NOTES:**

1. Bottom of pile cap honeycombed
2. North, South and West sides of pile scaled to 1/2 in. max. from pile cap down 3ft. Patch cracked.
3. Southwest and Southeast corners scaled to 1 in. max., 3ft. long, from 1ft. below pile cap.

**DESIGN LOADS:**

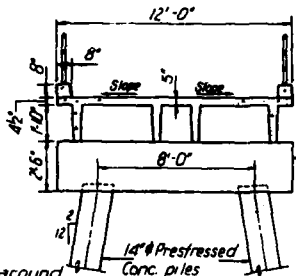
Live Load: H-10 AASHTO  
Wind: 122 mph  
Current: 4.5 knots  
Seismic: Zone 3

**GENERAL NOTES:**

This drawing was developed in part from NAVFAC Drawg Nos. 5095574 & 5095575. All piles were given a Level I inspection. All piles were found to be in good condition except as noted. Piles are shown oversized for clarity. +Channel bottom elevations Datum M.L.W. El. 0.0

40'-0"

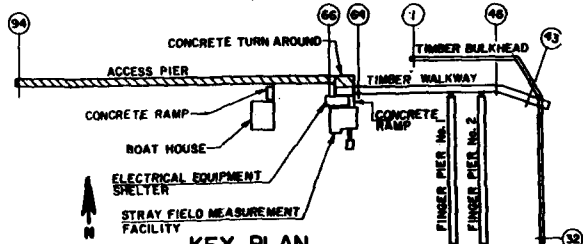
12'-0"



For Turn around pile plan see Fig. 4.1-3

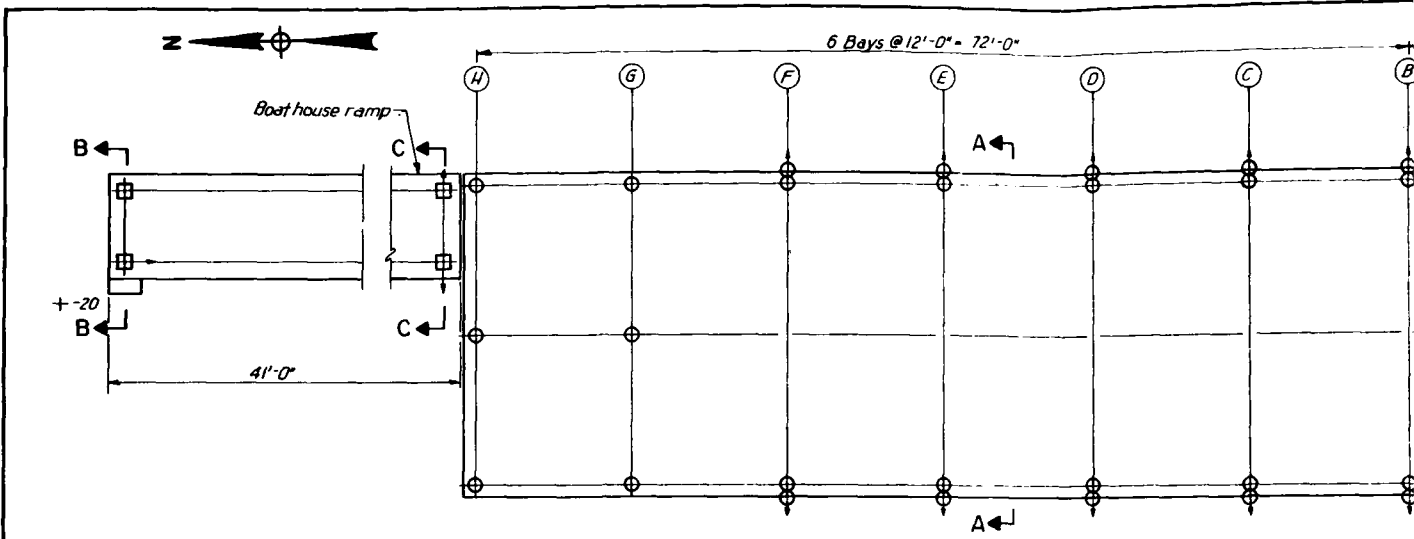
**SECTION A-A**

Scale: 1/4" = 1'-0"

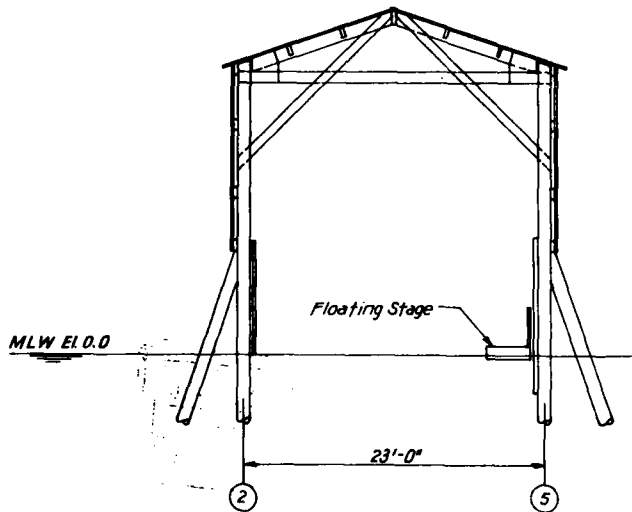


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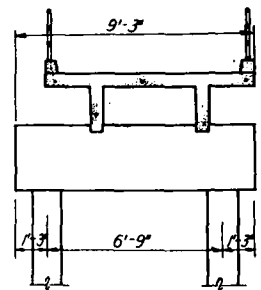
CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.  
NAVAL STATION CHARLESTON, S.C.  
PIER YANKEE  
**ACCESS PIER**  
CONTRACT No. N62477-82-2-0387



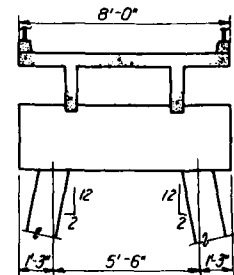
**PLAN**  
Scale:  $\frac{3}{16}" = 1'-0"$



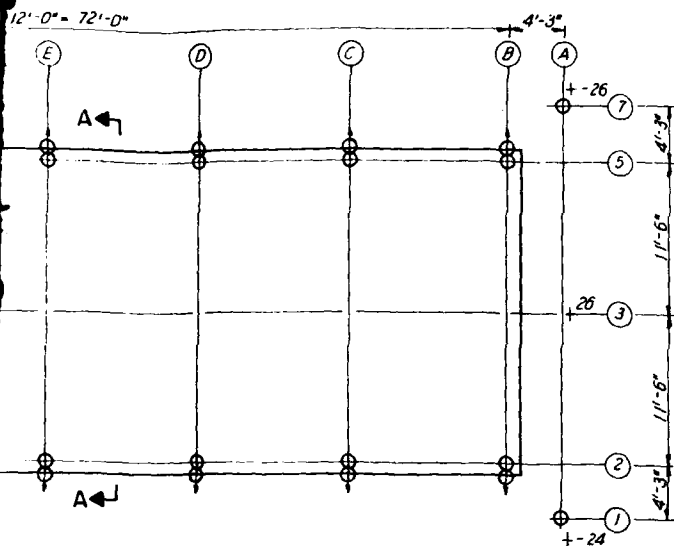
**SECTION A-A**  
Scale:  $\frac{3}{16}" = 1'-0"$



**SECTION B-B**  
Scale:  $\frac{3}{8}" = 1'-0"$



**SECTION C-C**  
Scale:  $\frac{3}{8}" = 1'-0"$



#### GENERAL NOTES:

This drawing was developed in part from Y. & D.  
 Drwg. No. 968973, A NAVFAC Drwg. Nos. 5095578, 5095579  
 All timber piles received a Level II and a Level III  
 inspection except piles 1A and 7A, which  
 received a Level II inspection only.  
 Piles are shown oversized for clarity.  
 + Channel bottom elevations.  
 Datum M.L.W. O.D.

#### DESIGN LOADS:

Boathouse:

Live Load

A. Roof: 20 psf

B. Floors & Walkways 100 psf

Wind Load 25 psf

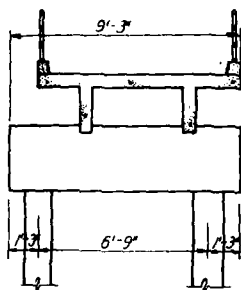
Ramp

Live Load: H-10 AASHTO

Wind: 122 mph

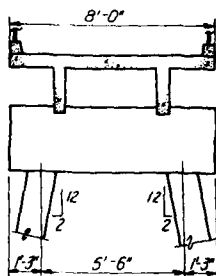
Current: 4.5 Knots

Seismic: Zone 3



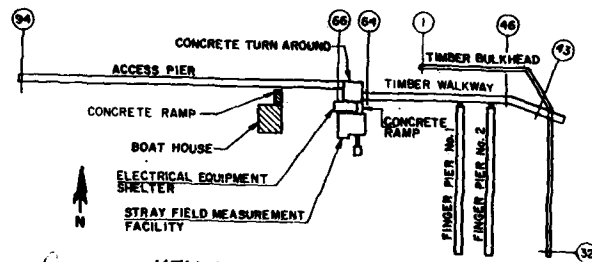
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Scale:  $\frac{3}{8}$ " = 1'-0"



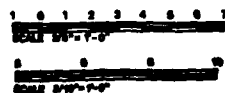
SECTION C-C

Scale:  $\frac{3}{8}$ " = 1'-0"



KEY PLAN

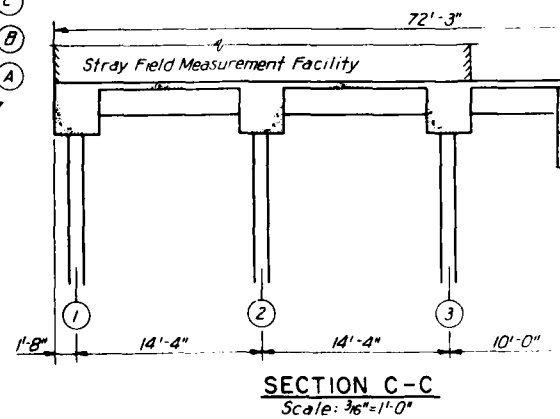
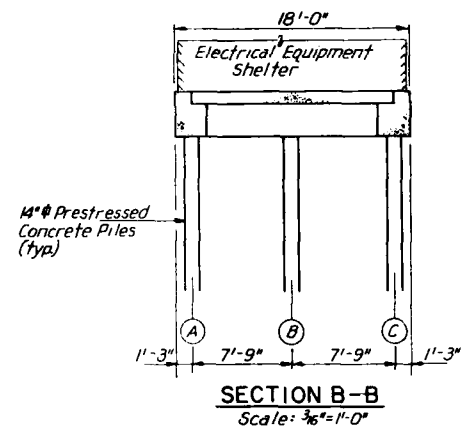
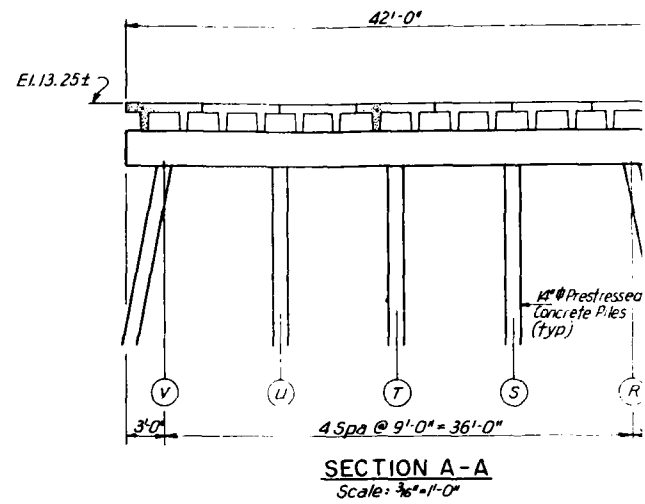
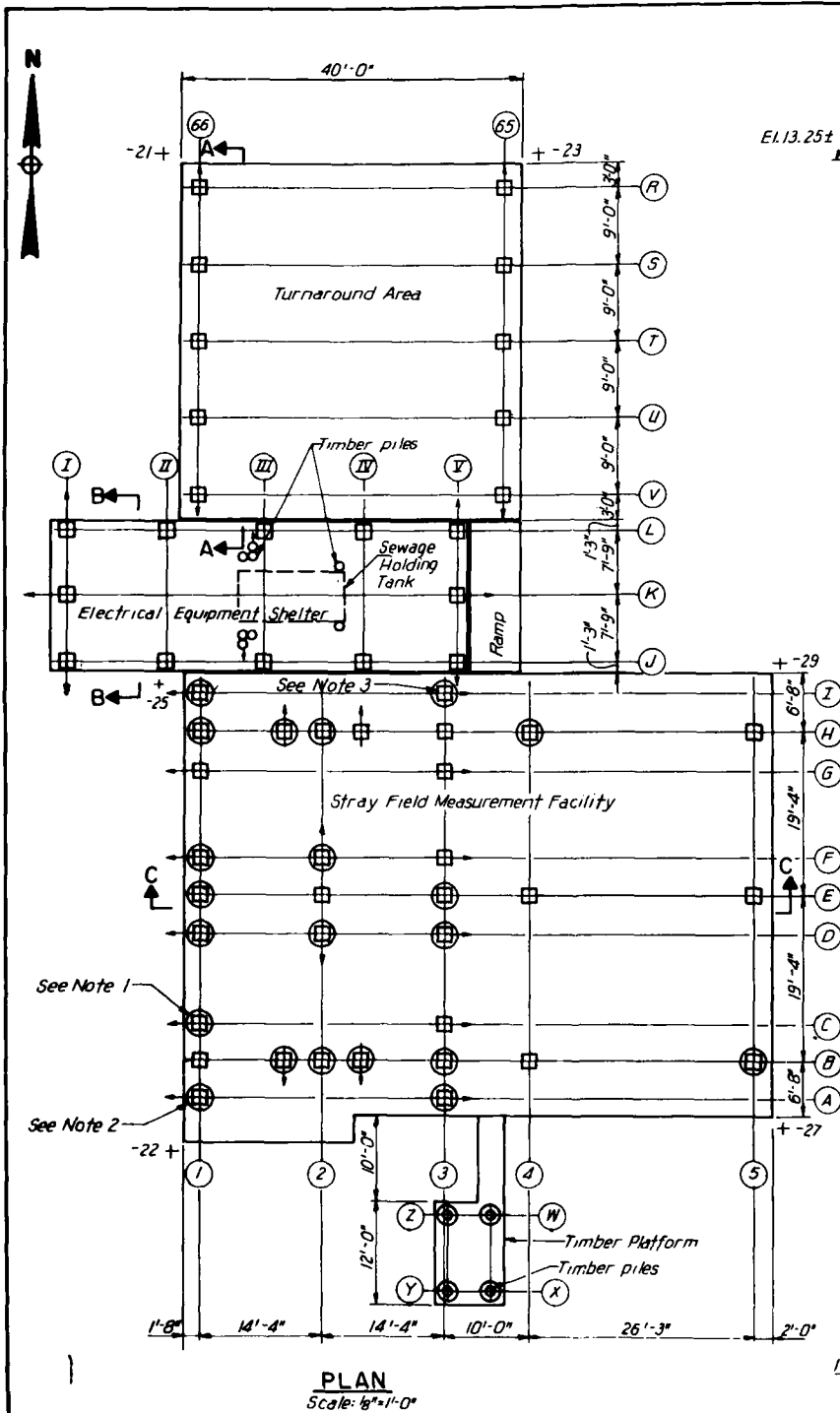
NO SCALE

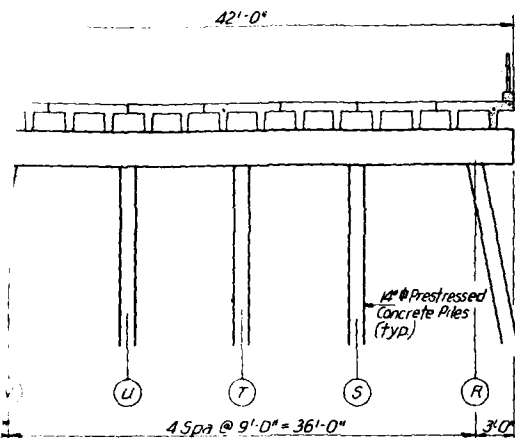


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CHESAPEAKE DIVISION  
 NAVAL FACILITIES ENGINEERING COMMAND  
 WASHINGTON, D.C.  
 NAVAL STATION CHARLESTON, S.C.  
 PIER YANKEE  
**BOAT HOUSE &  
 NEW CONCRETE RAMP**  
 CONTRACT No. N62477-83-D-9387

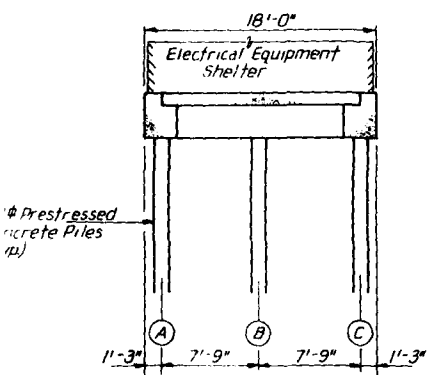






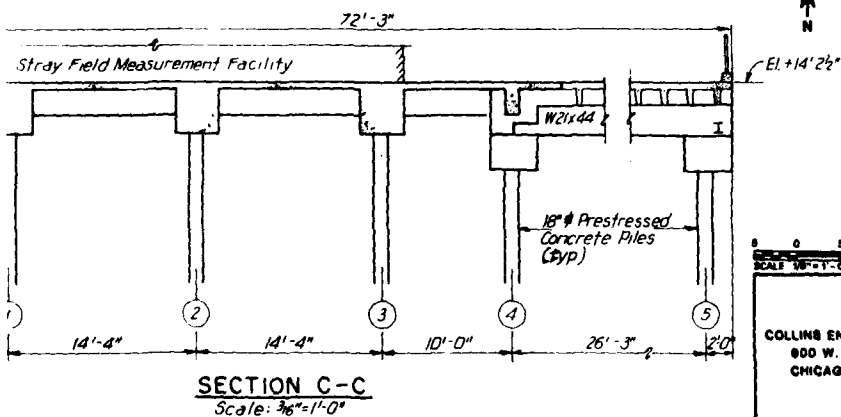
**SECTION A-A**

Scale:  $\frac{3}{8}'' = 1'-0''$



**SECTION B-B**

Scale:  $\frac{3}{8}'' = 1'-0''$



**SECTION C-C**

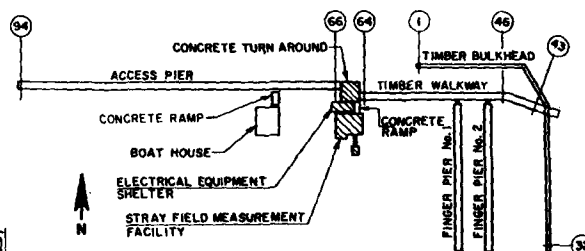
Scale:  $\frac{3}{8}'' = 1'-0''$

**GENERAL NOTES:**

This drawing was developed in part from NAVFAC Drwg. Nos. 5073933, 5095575, 5095576, 5095578, 5095579, 5095585, 5095586 and Y.I.D. Drwg. No. 968979.  
All piles received a Level I inspection.  
Piles marked thus @ received a Level II inspection.  
All piles were found to be in good condition.  
Piles are shown oversized for clarity.  
+ Channel bottom elevations  
Datum M.L.W. El. 0.0

**Notes:**

1. Crack  $\frac{1}{8}$  in wide on northwest corner from +4 to 0
2. Rust stained area 6 in. wide x 2 in. high, 2 ft. below pile cap.
3. Crack  $\frac{1}{8}$  in. wide on northwest corner from pile cap to mudline.



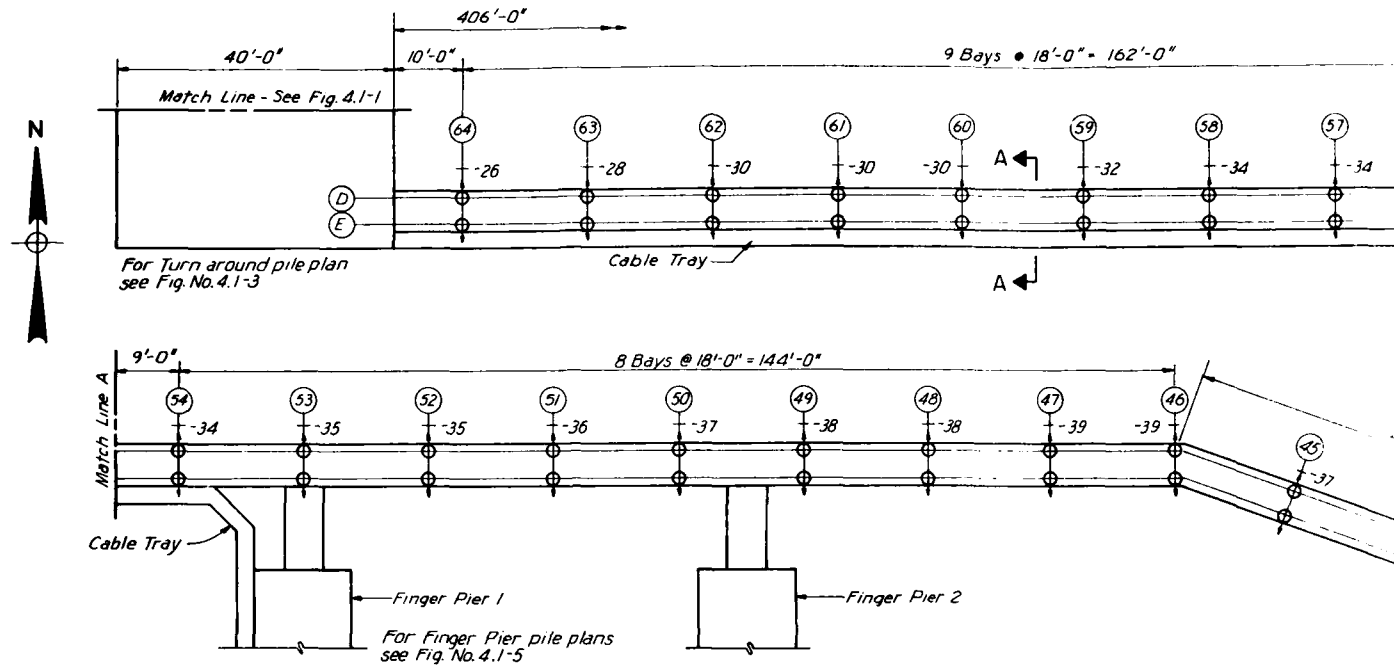
**KEY PLAN**  
NO SCALE



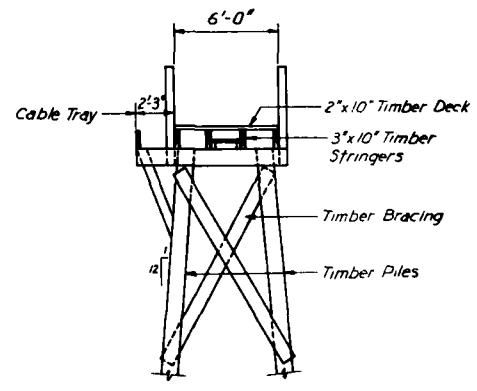
COLLINS ENGINEERS, INC.  
800 W. JACKSON  
CHICAGO, ILLINOIS

CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.  
NAVAL STATION CHARLESTON, S.C. FIG. NO.  
PIER YANKEE  
**TURNAROUND & BUILDING AREA**  
CONTRACT No. N62477-83-D-0387

4.1-3

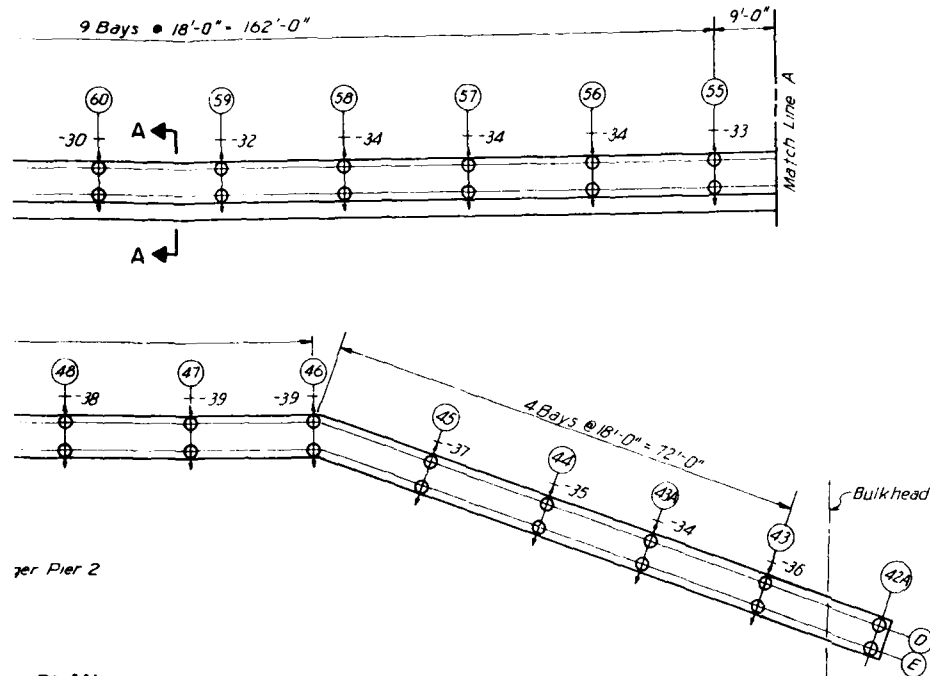


**PLAN**  
Scale: 1"=10'-0"

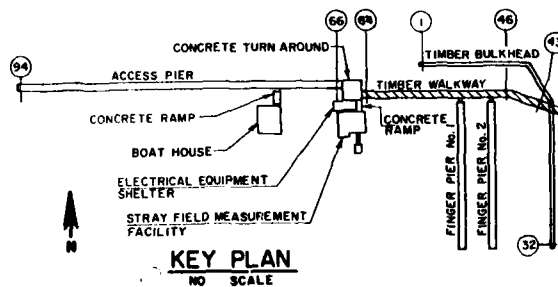
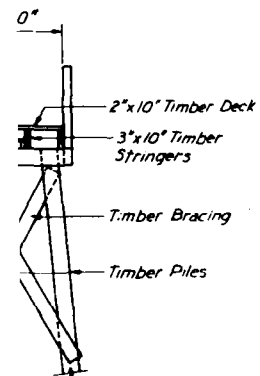


**SECTION A-A**  
Scale: 1/4"=1'-0"

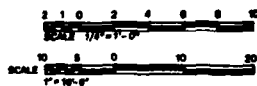
This drawing was developed in part from NAVFAC Drawg. Nos. 5095575, 5095581 & 5095582.  
All piles were given a Level I inspection.  
All piles were found to be in good condition.  
Piles are shown oversized for clarity.  
+ Channel bottom elevations  
Datum M.L.W. El. 0.0



**PLAN**  
Scale 1"=10'-0"



A - A  
• 1'-0"



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**CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.**

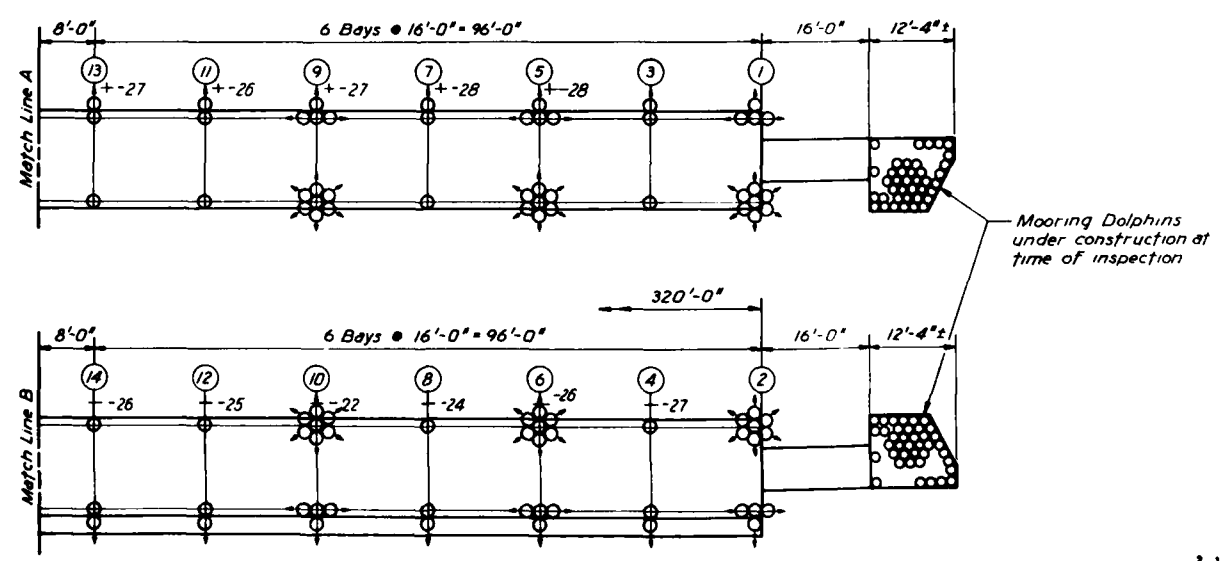
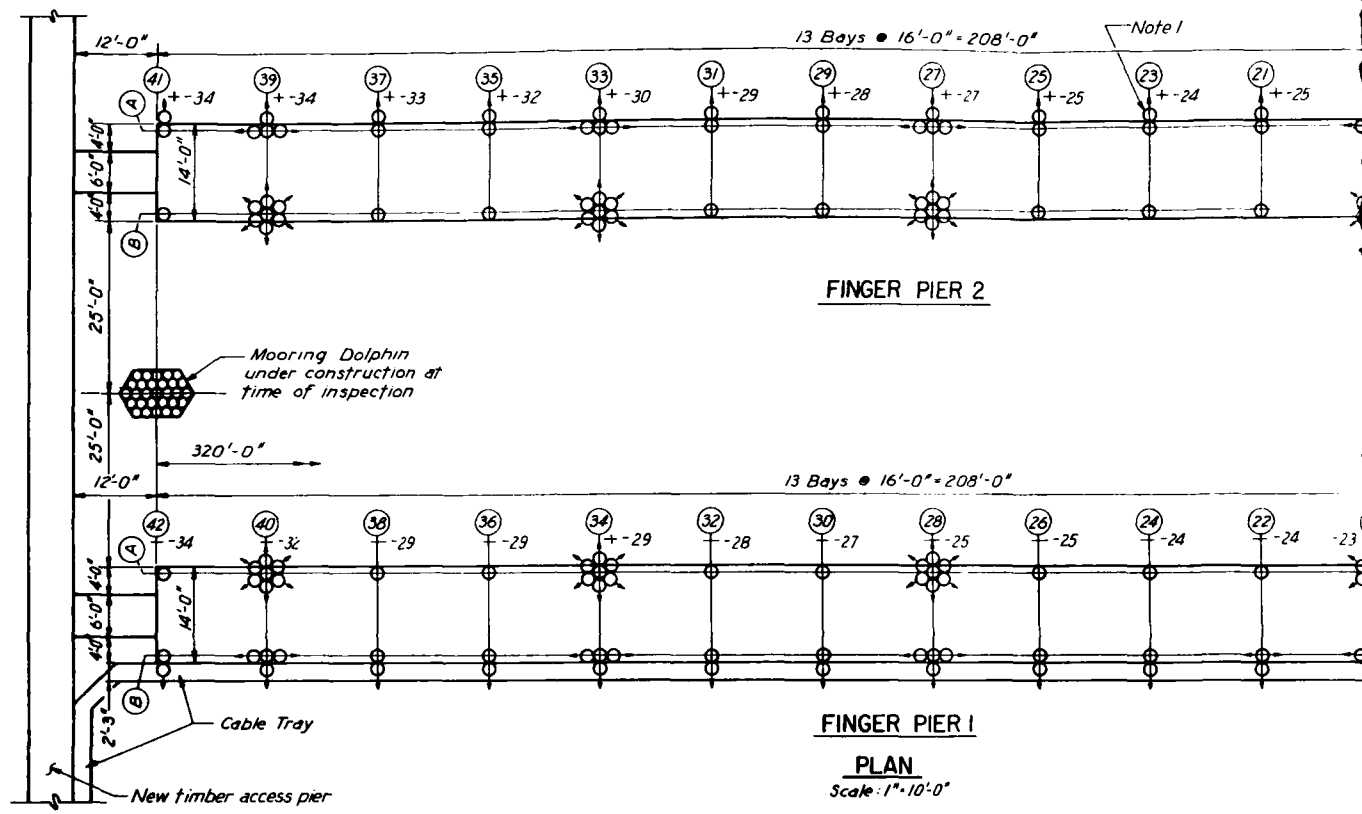
NAVAL STATION	CHARLESTON, S.C.	FIG. NO.
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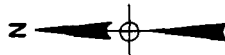
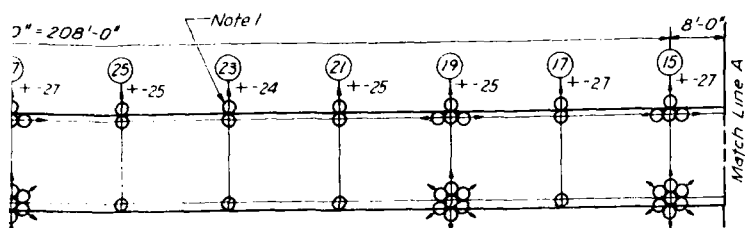
## TIMBER WALKWAY

**CONTRACT No. N62477-63-D-9387**

FIG. NO.

4.1-4





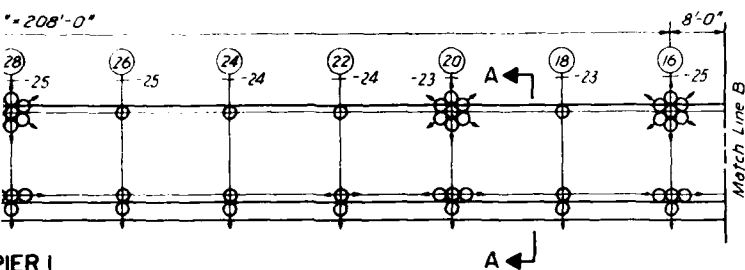
#### GENERAL NOTES:

This drawing was developed in part from NAVFAC Drawg. Nos. 5095582 & 5095583. All piles were given a Level I inspection. All piles were found to be in good condition. Piles are shown oversized for clarity. + Channel bottom elevations Datum M.L.W. El. 0.0

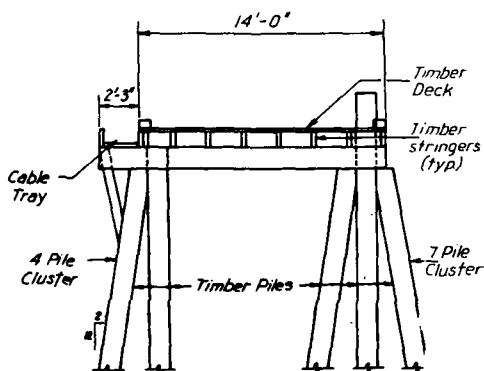
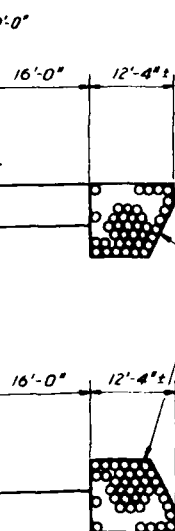
#### Notes:

1. North and South horizontal braces broken at water line.

PIER 2

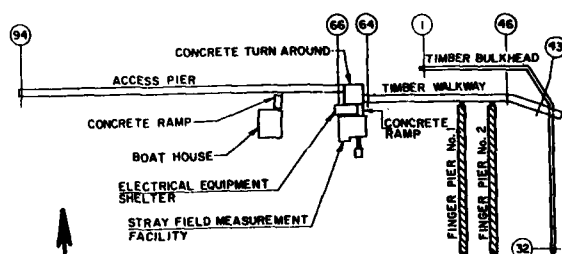


PIER 1



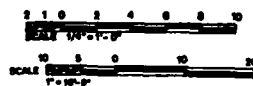
#### SECTION A-A

Scale: 1/4" = 1'-0"

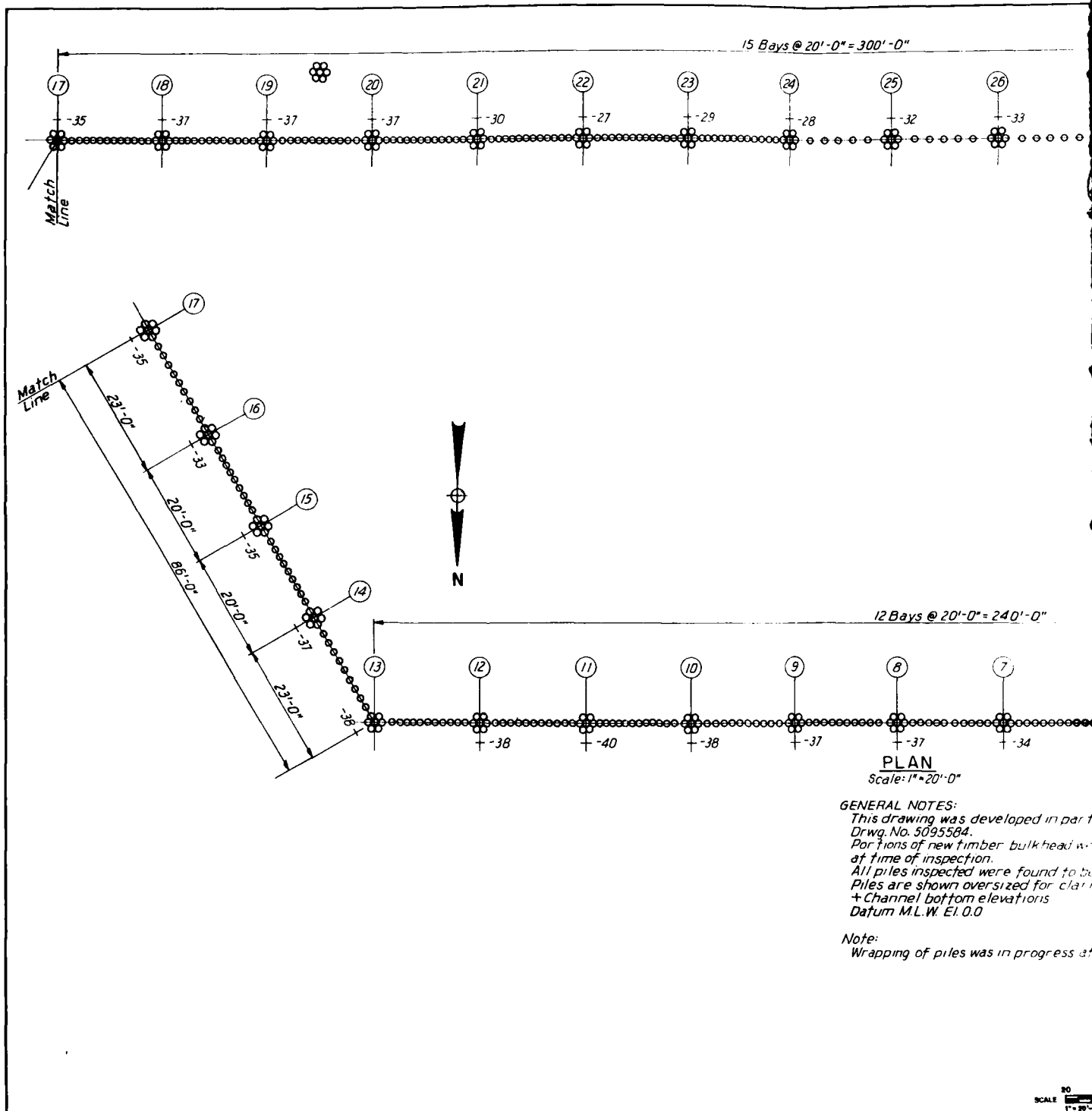


#### KEY PLAN

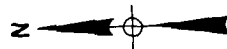
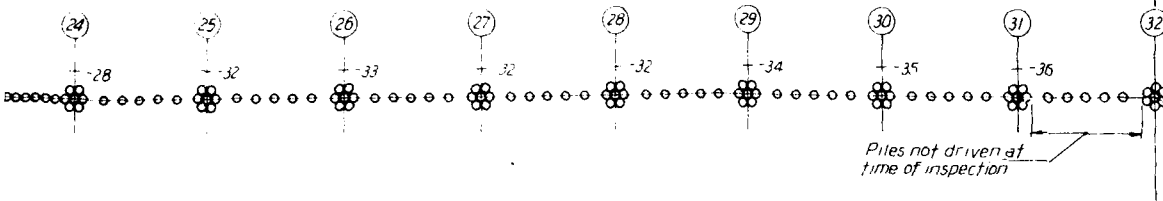
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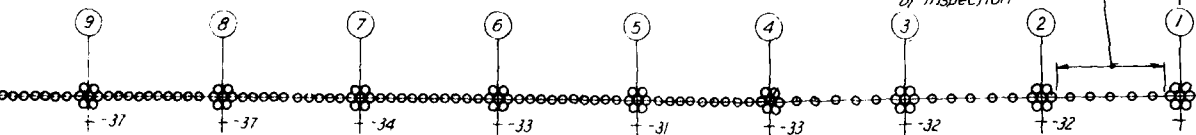
COLLINS ENGINEERS, INC. 800 W. JACKSON CHICAGO, ILLINOIS	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
	NAVAL STATION CHARLESTON, S.C. FIG. NO. PIER YANKEE	
	FINGER PIERS 1 & 2	
	CONTRACT No. N82477-93-D-9387	



15 Bays @ 20'-0" = 300'-0"



12 Bays @ 20'-0" = 240'-0"



# PLAN

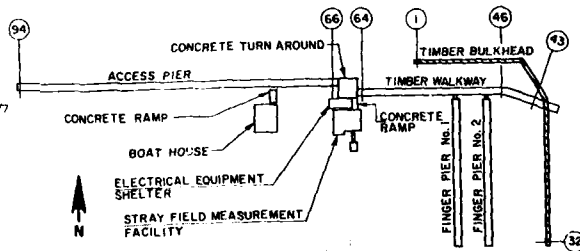
Scale: 1" = 20'-0"

## GENERAL NOTES:

This drawing was developed in part from NAVFAC  
 Drwg. No. 5095584.  
 Portions of new timber bulkhead were under construction  
 at time of inspection.  
 All piles inspected were found to be in good condition.  
 Piles are shown oversized for clarity.  
 + Channel bottom elevations  
 Datum M.L.W. El. 0.0

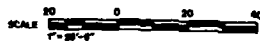
## Note:

Wrapping of piles was in progress at time of inspection.



## KEY PLAN

NO SCALE



COLLINS ENGINEERS, INC.  
 800 W. JACKSON  
 CHICAGO, ILL. 60618

CHEESAPEAKE DIVISION  
 NAVAL FACILITIES ENGINEERING COMMAND  
 WASHINGTON, D.C.

NAVAL STATION CHARLESTON, S.C.  
 PIER YANKEE

TIMBER BULKHEAD

CONTRACT No. N02477-83-D-0387

FIG. NO.  
 4.1-6





PHOTOGRAPH 4.1-1 Access Pier, Looking West,  
Pier Yankee.

PHOTOGRAPH 4.1-2 Boathouse, Looking Northeast,  
Pier Yankee.



building supported on a concrete pier structure approximately 52 feet by 67 feet. The westerly portion of the structure consists of 9 vertical and 18 batter precast, prestressed concrete piles supporting cast-in-place concrete pile caps and a cast-in-place concrete deck. The easterly portion of the structure which was added subsequent to the original construction consists of six vertical precast, prestressed concrete piles with cast-in-place concrete pile caps supporting steel beams which support precast, prestressed concrete double-T beams which are overlain with a concrete topping. Attached to the south side of the structure is a timber deck walkway and platform supported by 4 timber piles. The water depth near the stray field measurement building varies from approximately 22 to 29 feet. Refer to Figure 4.1-3 for a plan of the stray field measurement building and a typical section showing the configuration of the structure. Refer to Photograph 4.1-3 for a view of this facility.

There is a single span concrete structure connecting the turnaround area to the stray field measurement building. It is a precast prestressed concrete double-T span supported by the stray field measurement facility and the turnaround area structure. Refer to Figure 4.1-3 for a plan of the ramp.

An electrical equipment shelter is located between the turnaround structure and the stray field measurement facility. This is a rigid frame metal building supported on a concrete structure consisting of 12 precast, prestressed concrete piles with cast-in-place pile caps and a cast-in-place slab. Beneath the concrete deck, eight timber piles support a metal sewage holding tank. Refer to Figure 4.1-3 for a plan of the structure and a typical section showing the configuration of the structure.

The timber walkway providing access to the finger piers is approximately 406 feet long by 6 feet wide. It is constructed of 46 timber bearing piles with timber pile caps which support timber stringers and a timber deck. The water depth along the walkway varies from about 26 feet near the turn around area to a maximum of about 39 feet near the outboard end. A timber cable tray is attached to the south side of the walkway from the turnaround area to Finger Pier 1. Refer to Figure 4.1-4 for a plan of the structure and a typical section showing the configuration of the structure. Refer to Photograph 4.1-4 for a view of the outboard end of the timber walkway.

Finger Piers 1 and 2 are each 208 feet long by 14 feet wide. A 12 feet long by 6 feet wide walkway connects each finger pier to the timber walkway. The finger piers each consist of 238 timber piles with timber pile caps supporting timber stringers and a timber deck. Some of these piles also serve as dolphins in the slip formed by the two piers. A 29 pile timber mooring dolphin is located between the finger piers near the timber access walkway, and a 19 pile timber mooring dolphin is located at the south end of each finger pier. The water depth along the finger piers varies from about 24 to 34 feet. Refer to Figure 4.1-5 for a plan of the Finger Piers 1 and 2 and a typical section showing the configuration of the structures. Refer to Photograph 4.1-5 for a



PHOTOGRAPH 4.1-3 Stray Field Measurement Building  
Looking North, Pier Yankee.

PHOTOGRAPH 4.1-4 View of Timber Walkway, Looking  
North near Outboard End, Pier  
Yankee.



view of Finger Pier 2.

A continuous timber pile bulkhead is located to the north and east of the finger piers. It is approximately 626 feet long and includes 32 7-pile timber clusters and 267 individual bulkhead piles. The pile clusters and individual bulkhead piles are connected by wrapping each pile or cluster with wire rope and stapling the wire rope to the piles. One additional, individual 7-pile cluster is located near the north end of the north-south leg of the bulkhead. The water depth along the bulkhead varies from about 24 feet to 34 feet. Refer to Figure 4.1-6 for a plan of the bulkhead. Refer to Photograph 4.1-6 for a view of the northeast corner of the bulkhead.

The range marker pole is located approximately one-half mile upstream near the east shore. It consists of a single timber pile to which is attached a vertical white board approximately 6 feet long by 4 inches wide.

The design loads for the structure being completed in 1984 are :

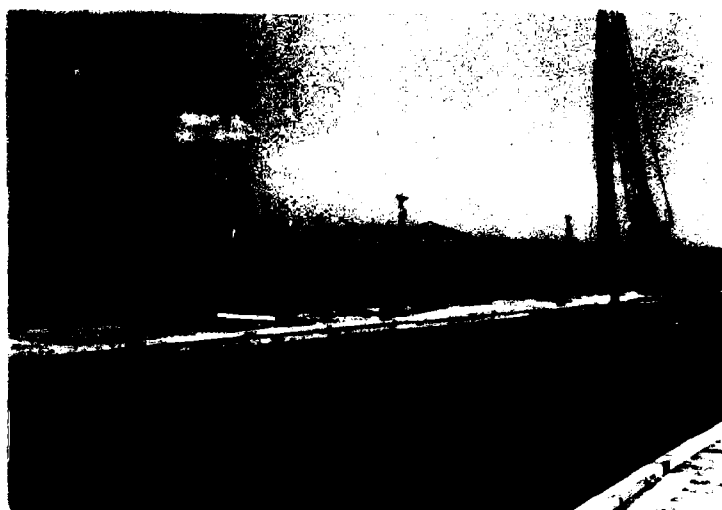
Live Loads:	
Concrete Pier	AASHTO H-10
Timber Pier	50 pounds per square foot
Wind Loads:	
Pier	122 miles per hour
Mooring Dolphins	70 miles per hour (vessel in slip)
Current:	4.5 knots
Seismic	Zone 3

The stray field measurement building was designed for the following loads:

Roof Loads:	20 pounds per square foot
Floor Loads:	
Toilets	60 pounds per square foot
Office, Berthing, Corridor and Instrument Room	75 pounds per square foot
Stairs	100 pounds per square foot
Shop and Storage	150 pounds per square foot
Files and Prints	200 pounds per square foot

The boat house was designed for the following loads:

Live Load:	
Roof	20 pounds per square foot
Floor and Walkways	100 pounds per square foot
Wind Load:	25 pounds per square foot



PHOTOGRAPH 4.1-5 Finger Pier 2, Looking Southeast,  
Pier Yankee.

PHOTOGRAPH 4.1-6 Timber Bulkhead, Looking North,  
Pier Yankee.



The stray field measurement building platform extension was designed for the following loads:

Live Load:	100 pounds per square foot
Wind Load:	40 pounds per square foot
Seismic:	Zone 2

#### 4.1.2 Observed Inspection Condition

At the time of the inspection, work was still in progress on the bulkhead, timber walkway, and mooring dolphins. The inspection, therefore, did not include approximately 20 feet at each end of the bulkhead; the east two bents of the timber walkway; the 29-pile mooring dolphin between the finger piers; nor the 19 pile mooring dolphin at the south end of Finger 2.

The prestressed concrete piles of the access pier, turnaround area, and equipment shelter area were in excellent condition. No evidence of damage or deterioration was found. Refer to Photograph 4.1-7 for a view of Pile 68C which is a typical new prestressed concrete pile that has been cleaned of the minor growth accumulated thus far. There were, however, two minor areas of honeycombed concrete on the bottom surface of the pile caps of Bent 73. There were also minor scaled areas on two piles, near the pile caps of Bent 80. Refer to Figure 4.1-1 for the detailed inspection notes.

The prestressed concrete piles of the stray field measurement building were in good condition except for three piles. Pile 1A has a rust stained area 6 inches wide by two feet high near the waterline as shown in Photograph 4.1-8; Pile 1C has a 1/16 inch wide crack approximately 4 feet long near the pile cap; and Pile 3I has a 1/16 inch wide crack extending from the pile cap to the mudline as shown in Photograph 4.1-9. Refer to Figure 4.1-3 for the detailed inspection notes.

The timber piles of the newly constructed timber walkway, finger piers, bulkhead and dolphins are in excellent condition. It was noted, however, that the horizontal timber brace supporting the light pole at Bent No.23 of Finger Pier 2 had been broken as shown in Photograph 4.1-10. Refer to Figures 4.1-3 through 4.1-6 for the pile plans and detailed inspection notes. It was also noted that two field changes were made from the design plans which changed the location of the east end of the timber walkway and changed the location of the walkway connections between the timber walkway and the finger piers. The figures in the report reflect those changes.

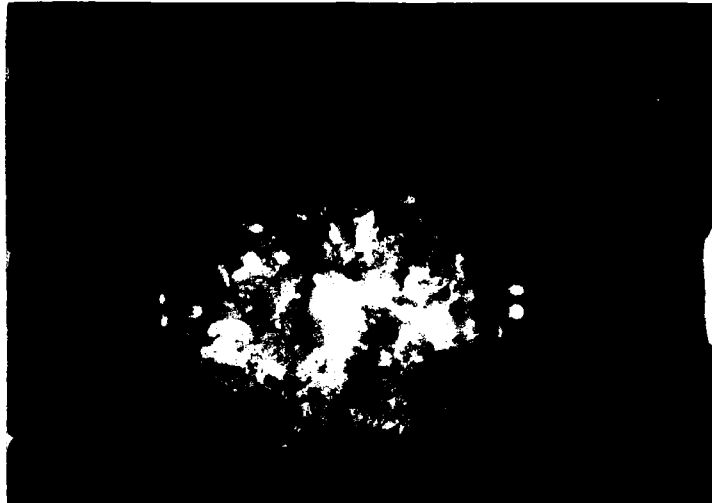
The timber piles of the boat house are in good condition, although they have suffered general surface damage from marine borers, limnoria. Refer to Photographs 4.1-11 and 4.1-12



PHOTOGRAPH 4.1-7 Typical Pile of Access Pier,  
Pile 68C, Pier Yankee.

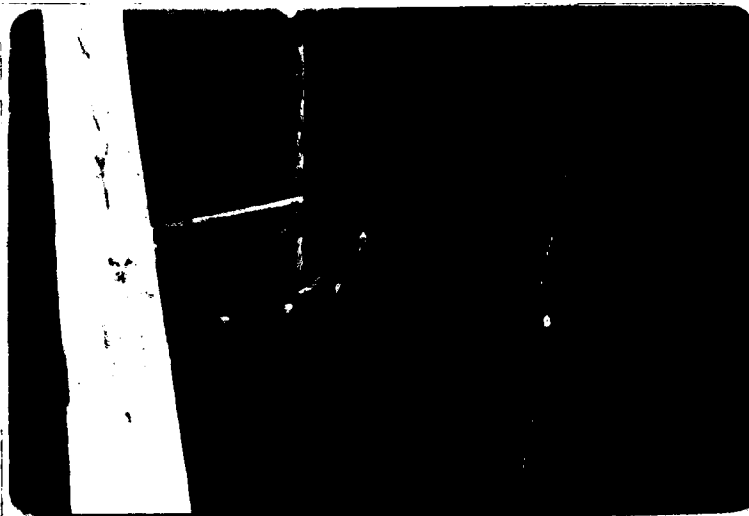
PHOTOGRAPH 4.1-8 Rust Stain on Pile 1A, Stray Field  
Measurement Building, Pier Yankee.





PHOTOGRAPH 4.1-9 1/16 inch Vertical Crack on Right  
Corner of Pile 3I, Stray Field  
Measurement Building, Pier Yankee.

PHOTOGRAPH 4.1-10 Broken Horizontal Bracing,  
Bent 23, Finger Pier 2, Pier  
Yankee.





for views of Pile 3H which is typical of the piles of the boat house. Cores, borings and ultrasonic inspection of the piles indicated that the piles are sound and borer damage has not significantly reduced the load carrying capacity of the structure. Listed below are the field measurements of pile diameters, wave velocity for the piles, and estimated dry crushing strength for each pile. These strengths were estimated from the field data using the charts contained in the Appendix. Generally, two readings were taken at right angles near mean low water, at Elevation -5 and at Elevation -10.

<u>Pile No</u>	<u>Diameter (Inches)</u>	<u>Wave Velocity Range (Ft per second)</u>	<u>Estimated Dry Crushing Strength (Psi)</u>
5D	12 1/2 to 13 3/8	5100 to 5900	4600
5D/B	14 3/4 to 14 7/8	5500 to 5700	4600
5E	12 1/8 to 12 5/16	4100 to 4800	3800
5E/B	12 5/8 to 12 9/16	4300 to 5400	4000
5F	10 7/8 to 11 5/8	4600 to 5900	4400
5F/B	13 7/8 to 14 5/8	5400 to 5500	4600
3G	14 7/8 to 15 1/4	4800 to 4900	4000
4G	11 15/16 to 12 1/4	5400 to 6200	4800
5G	12 5/8 to 13 5/16	5600 to 6400	5000
3F	13 7/8	6000 to 6300	5000
3F/B	13 to 11 15/16	4000 to 4400	3600
3E	14 3/4 to 14 15/16	4900 to 5900	4600
3E/B	13 1/8 to 13 11/16	4300 to 4800	3800
3D	13 1/4 to 13 3/4	4400 to 5100	4000
3D/B	12 7/8 to 13	3800 to 5000	3800
3C	13 15/16	5300	4400
3 C/B	12 5/8 to 13 1/16	4900 to 5200	4200
3B	12 1/4 to 12 5/16	4100 to 4400	3600
3B/B	12 15/16 to 13 1/2	4600 to 4800	4000
5B	13 1/8 to 13 5/8	4400 to 5100	4000
5B/B	13 1/2 to 13 5/8	5600 to 5700	4800
5C	13 3/8 to 13 5/16	5200 to 5300	4400
5CB	14 1/16 to 14 9/16	3500 to 3600	2600
3H	13 3/4 to 14 1/16	4500 to 5100	4000
4H	12 1/2 to 12 5/16	6000 to 6200	5000
5H	13 1/16 to 13 5/16	5200 to 5400	4400

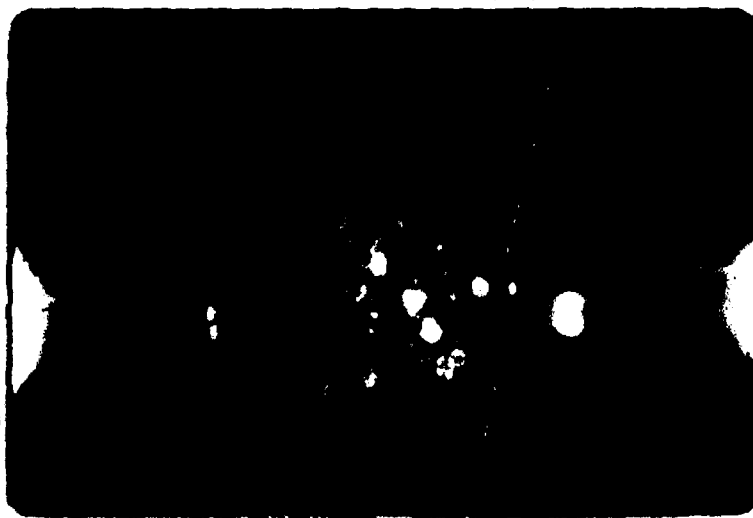
The timber piles of the structure adjacent to the stray field measurement facility likewise exhibited general surface damage near the waterline due to marine borer attack. This damage appears to be limited to the surface. The timber bracing near the waterline has suffered extensive damage as shown in Photograph 4.1-13.

The timber piles under the electrical equipment shelter have suffered similar marine borer damage at the waterline, but are in good condition below the waterline as shown in Photograph 4.1-14. The range marker pile is in fair condition, with surface marine borer attack, and it leans slightly as shown in Photograph 4.1-15.



PHOTOGRAPH 4.1-11 Typical Marine Growth at  
Boathouse, Pile 3H at Elevation  
-5, Pier Yankee.

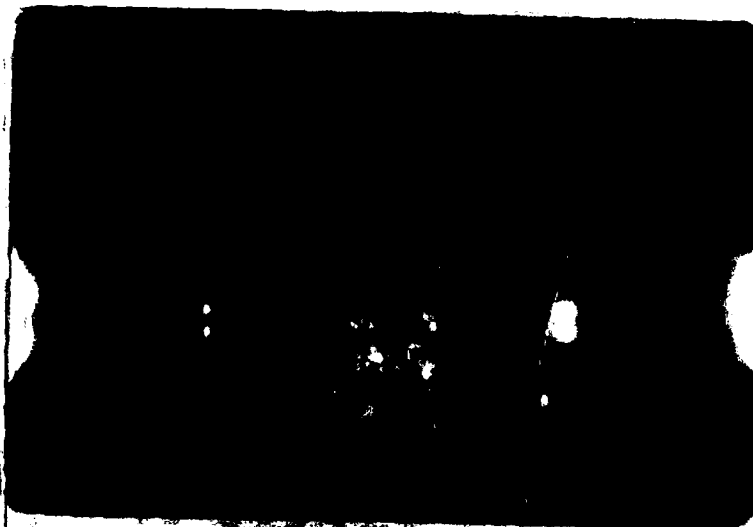
PHOTOGRAPH 4.1-12 Typical Timber Pile at Boathouse,  
Pile 3H at Elevation -8, Pier  
Yankee.

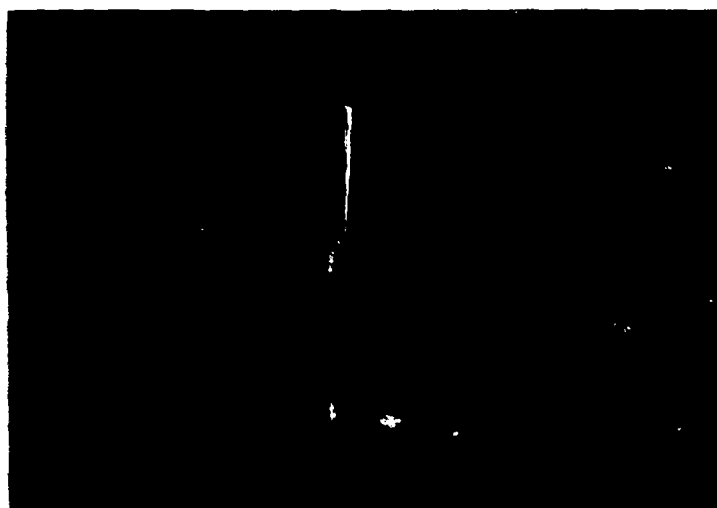




PHOTOGRAPH 4.1-13 Pile 3Y at Waterline, Timber  
Platform of Stray Field  
Measurement Building, Pier  
Yankee.

PHOTOGRAPH 4.1-14 Southwest Pile Supporting Tank,  
Electrical Equipment Shelter at  
Elevation -10, Pier Yankee.





PHOTOGRAPH 4.1-15 Range Marker Pile, Pier Yankee.

#### 4.1.3 Structural Condition Assessment

The prestressed concrete piles and the newly driven piles of Pier Yankee are generally in very good or excellent condition. The cracked and spalled areas of the three piles under the stray field measurement building, Piles 1A, 1C and 3I, however, do provide an area where water and oxygen can enter those piles and eventually cause more severe corrosion. While these defects have not significantly reduced the structural capacity of the piles at this time, they should be repaired to prevent further deterioration and corrosion which could eventually weaken the structure. The areas of honeycombed concrete, Bent 73, and scaling, Piles 80A inboard and outboard, of the newly constructed access pier have not reduced the structural capacity of the facility at this time, but could lead to further deterioration if not repaired.

The timber piles of the boat house, the tank under the equipment shelter, and the platform adjacent to the stray field measurement building have suffered surface damage from marine borers, but this deterioration has not significantly reduced the structural capacity of the facilities. In time, however, this borer attack can be expected to continue and eventually weaken these structures. The bracing of the platform structure is severely deteriorated and has lost most of its effectiveness.

The estimated dry crushing strength of the timber piles of the boat house generally ranged between 3600 and 4600 psi with a minimum pile diameter of 12 inches. Using allowable working stress of 900 to 1150 psi. This is within, although at the low end of, the range of usual design stresses for timber.

#### 4.1.4 Recommendations

It is recommended that the minor concrete defects noted on the two pile caps and two piles of the Access Pier be repaired and the broken horizontal brace on Finger Pier 2 be replaced. The estimated cost of this work, which should be the responsibility of the contractor now completing construction of these facilities, is approximately \$2,000.

The scaled area of one pile and the cracks in two other piles of the Stray Field Measurement Building should also be repaired with epoxy mortar. The estimated cost of these repairs is \$12,000. Refer to the Appendix (A-1) for a detailed cost estimate.

The timber piles of the Boat House and the structure adjacent to the Stray Field Measurement Building are approximately 20 years old. In that period, their structural capacity has not been significantly reduced by marine borer attack. The capacity of the Boat House piles, as determined by the ultrasonic measurements, indicated sufficient structural capacity. In addition, for the stray field facility, there also appears to be much more structural capacity than is needed. Further

deterioration of the piles can be expected, but the rate may be very slow so that taking other protective measures such as wrapping the piles with a protective system may not be economically warranted. It is recommended that the condition of these timber piles be monitored at an interval not to exceed three years to determine if the marine borer attack is progressing. If it is progressing, remedial measures can be taken in sufficient time to maintain the structural integrity of the facility. This approach would also allow reevaluation of the overall need for this facility in meeting the activity's mission.

It is also recommended that the newly constructed timber finger piers, walkways, and bulkhead be inspected at the same three year interval to determine if they will be subject to successful marine borer attack. This short interval inspection, would also permit the initiation of remedial measures in a timely fashion.

It is further recommended that the entire facility be reinspected at intervals of six years. The repairs recommended above should be inspected when they are completed.

## 4.2 Magnetic Silencing Facility, Downtown Charleston

### 4.2.1 Description

A portion of the Magnetic Silencing Facilities is located in downtown Charleston, South Carolina on the west bank of the Cooper River near its confluence with the Ashley River forming Charleston Harbor. Refer to Figure 2.2-3 for the location of MSF Downtown.

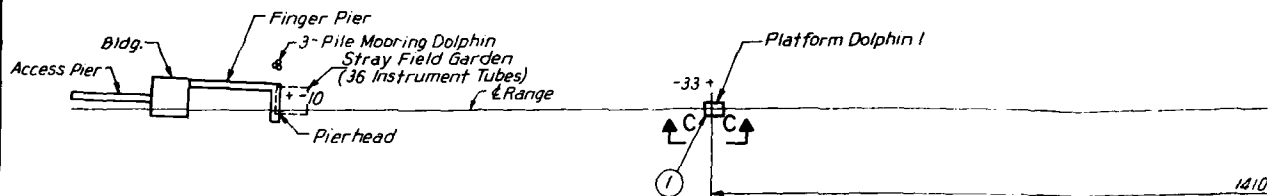
MSF Downtown includes an access pier, building, equipment platform east of the building, finger pier and pierhead; five platform dolphins; a mooring dolphin; a stray field garden; a shallow range in a rock-filled crib; and a medium range. The sensor tubes of the ranges are connected to the building by cables on the channel bottom. Refer to Figure 4.2-1 for a general plan of the facility.

The access pier, building, equipment platform, finger pier and pierhead consist of 46 batter and 14 vertical precast, prestressed concrete piles with cast-in-place concrete pile caps. The access pier, equipment platform, finger pier and pierhead deck consists of precast, prestressed concrete channels atop the pile caps. The deck channels are covered with a cast-in-place concrete topping. The floor of the building and the walk around the building is a cast-in-place concrete slab. This concrete facility extends approximately 295 feet from the shore. The water depth around these structures varies from zero near the shore to about 11 feet at the outboard end. A timber pile fender system extends along the east face of the pierhead. A three pile timber mooring dolphin is located near the north end of the pierhead. Refer to Figure No. 4.2-2 for a plan of the building and pier area and typical sections showing the configuration of the structure. Refer to Photographs 4.1-1 and 4.1-2 for views of the facility.

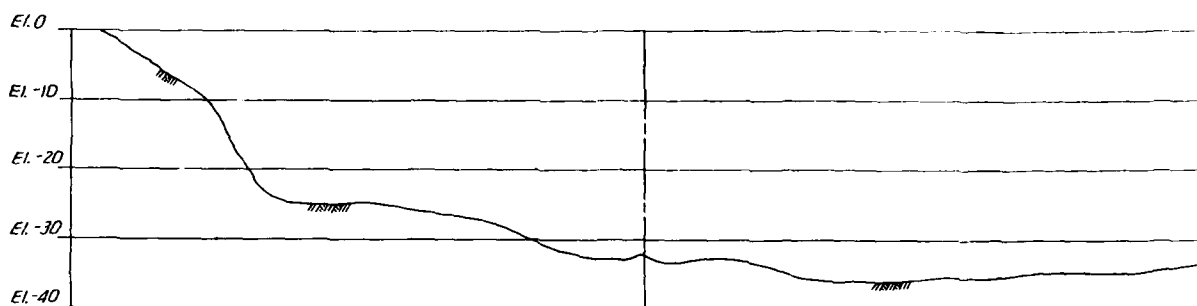
Five platform dolphins are located in the river to mark the position of sensing ranges and to provide areas for splicing cable runs to the sensing equipment. Platform Dolphin 1, the westernmost platform dolphin consists of four timber piles and three precast, prestressed concrete piles with a concrete cap supporting a timber platform. Platform Dolphins 2, 3, 4, and 5 each consist of four timber piles supporting a timber platform. Refer to Photographs 4.2-3 through 4.2-7 for views of the platforms. Refer to Figure 4.2-1 for plans and typical sections showing the configuration of the structures.

Between Platform Dolphins 2 and 3 there is a medium sensing range consisting of 12 sensors positioned in PVC pipes protruding from the channel bottom

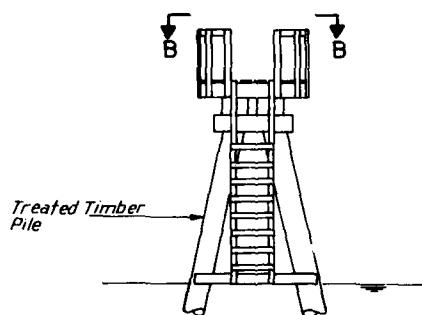
Between Platform Dolphins 4 and 5 a stone-filled timber crib approximately 63 feet long by 11 feet wide provides support for 12 sensing tubes. The crib was reconstructed in 1969 after it was damaged by scour. Refer to Figure 4.2-3 for a plan of the crib and a typical section showing the configuration of the structure.



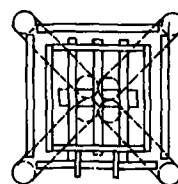
**PLAN**  
Scale: 1"=100'-0"



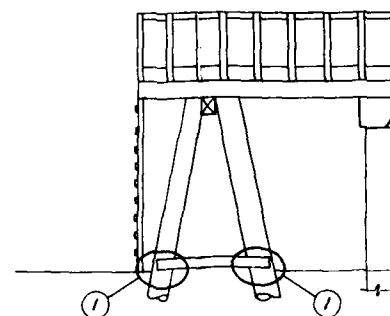
**PROFILE 20' ± NORTH OF RANGE CENTE**



**SECTION A-A**  
(Typical Platform Dolphins 2, 3, 4, 5)



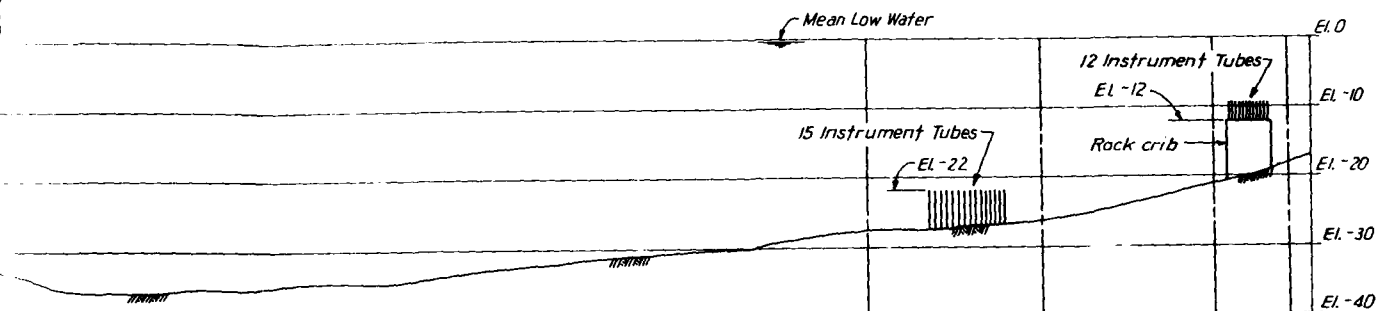
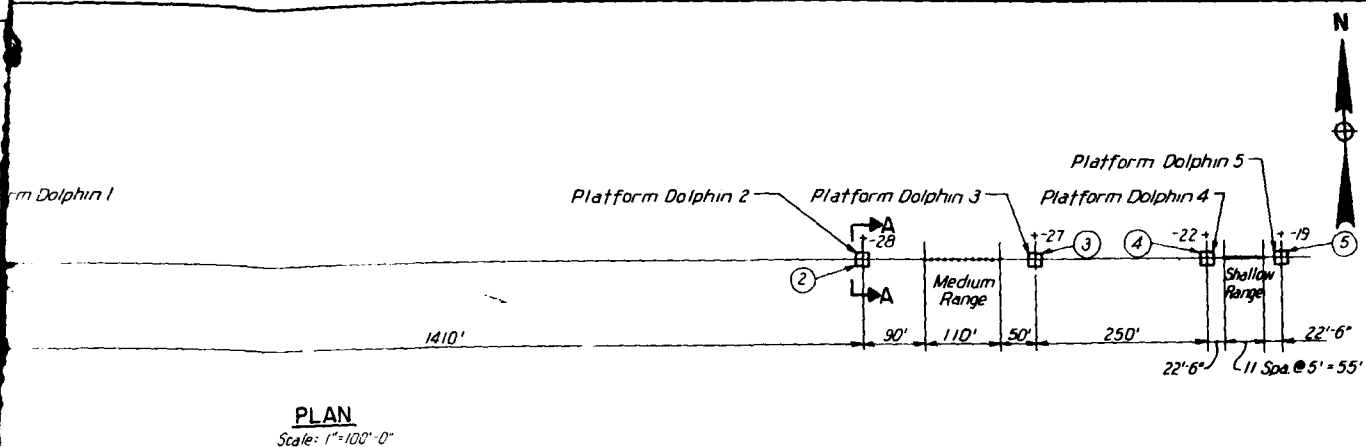
**SECTION B-B**



**SECTION C-C**  
(Platform Dolphin I)

NOT  
1. 1/4  
2. 1/2  
3. 2  
4. 1/4  
5.  
6.



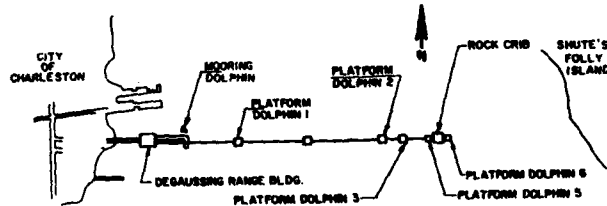
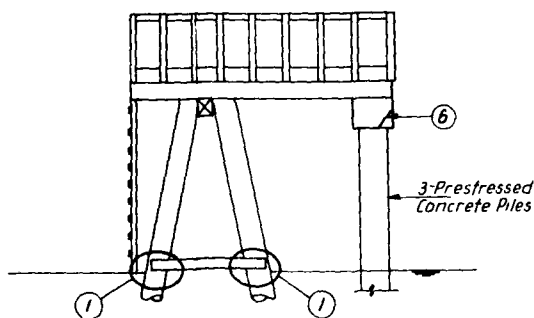


#### NOTES:

1. 10%-30% loss of section 4 piles for 2ft. at M.L.W.
2. 10%± loss of section of 4 piles for 2ft. at M.L.W.
3. 20%± loss of section of 4 piles for 2ft. at M.L.W.
4. 10%-25% loss of end of horizontal bracing for 1ft. at ends.
5. 10%± loss of section of piles for 2ft. at M.L.W.
6. 3 horizontal braces missing; 1 brace poor condition.
7. 10%± loss of section of piles for 2ft. at M.L.W.
8. 1 horizontal brace missing, 3 braces with 25%± loss of 1ft. at ends.
9. East face of cap cracked; bottom edge broken off.

#### GENERAL NOTES:

This drawing was developed in part from NAVFAC Drawing Nos. 1303032 & 5002271.  
All timber piles of Mooring Dolphin and Platform Dolphins 1-5 were given a Level II Inspection.  
All timber piles of Mooring Dolphin and Platform Dolphin 2-5 were given a Level III Inspection.  
Channel bottom profile based on soundings made August 16, 1984.



COLLINS ENGINEERS, INC.  
808 W. JACKSON  
CHICAGO, ILLINOIS

CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.

NAVAL STATION CHARLESTON, S.C. FIG. NO.

GENERAL PLAN

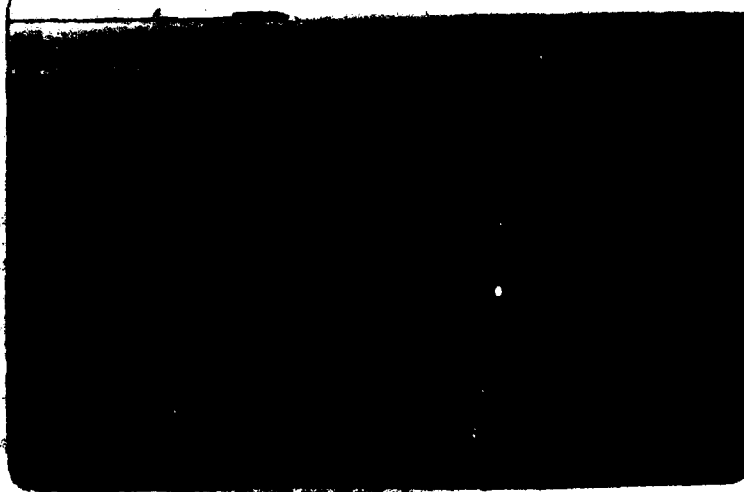
4.2-1

CONTRACT No. N82477-82-D-9387



PHOTOGRAPH 4.2-1 MSF Building, Looking West,  
MSF Downtown.

PHOTOGRAPH 4.2-2 Finger Pier and Pierhead,  
Looking East, MSF Downtown.





**GENERAL NOTES:**

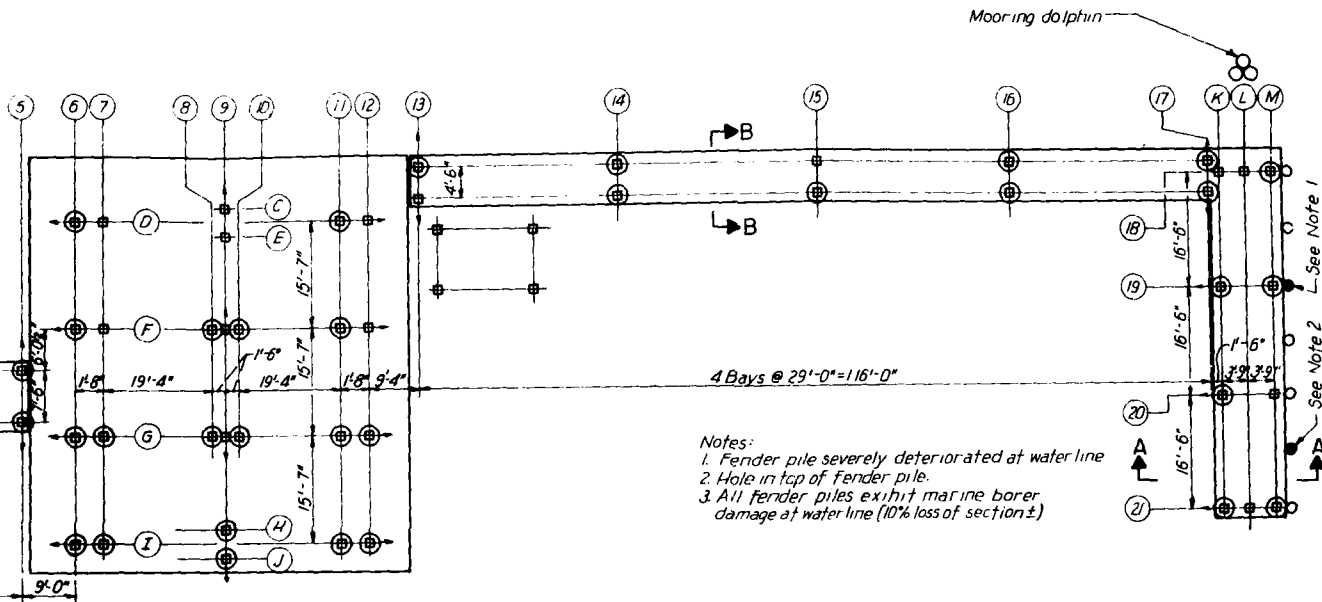
This drawing was developed in part from Y & D Drawing No. 912817

All piles were given a Level I inspection.

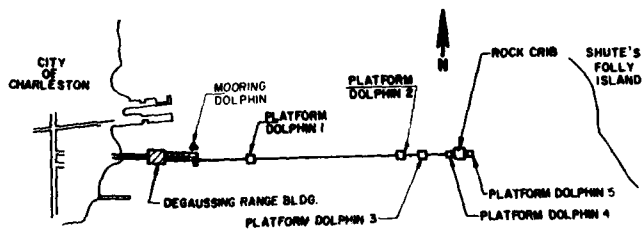
Piles marked thus (C) recieved a Level II inspection.

All piles were found to be in good condition except as noted.

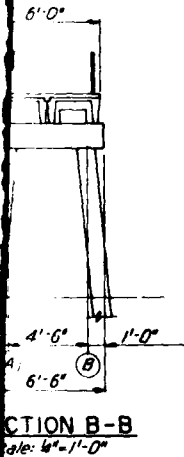
Piles are drawn oversized for clarity.



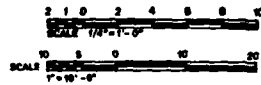
**PLAN**  
Scale: 1"=10'-0"



**KEY PLAN**  
NO SCALE

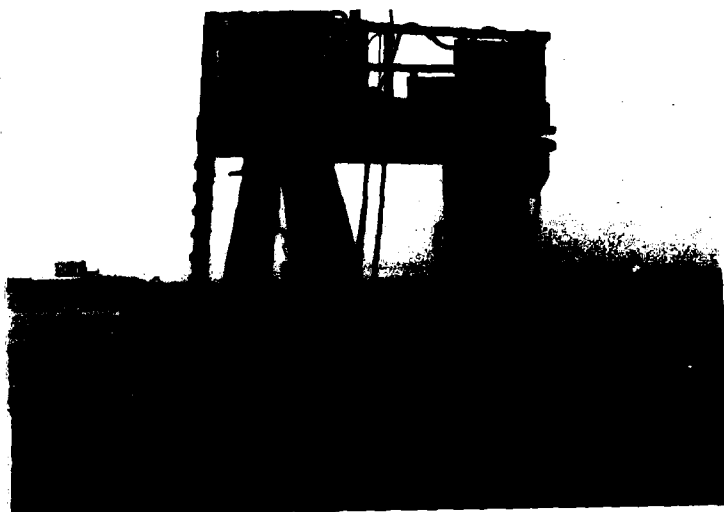


**SECTION B-B**  
Scale: 1/4"=1'-0"



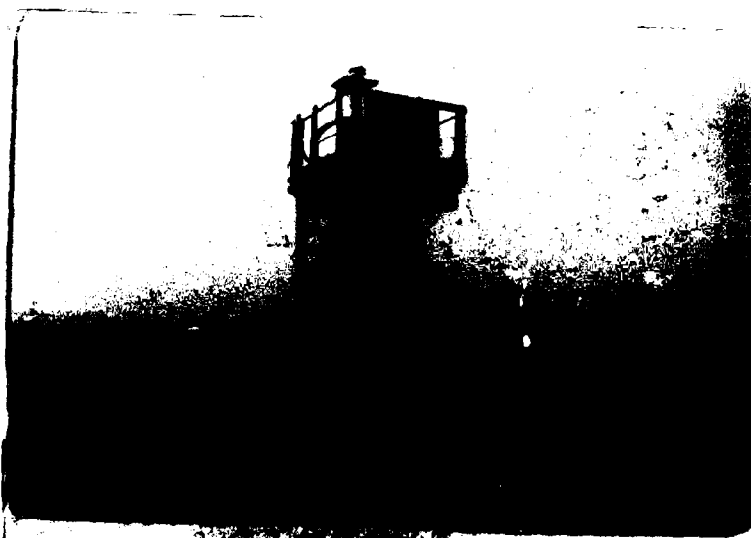
COLLINS ENGINEERS, INC.  
800 W. JACKSON  
CHICAGO, ILLINOIS

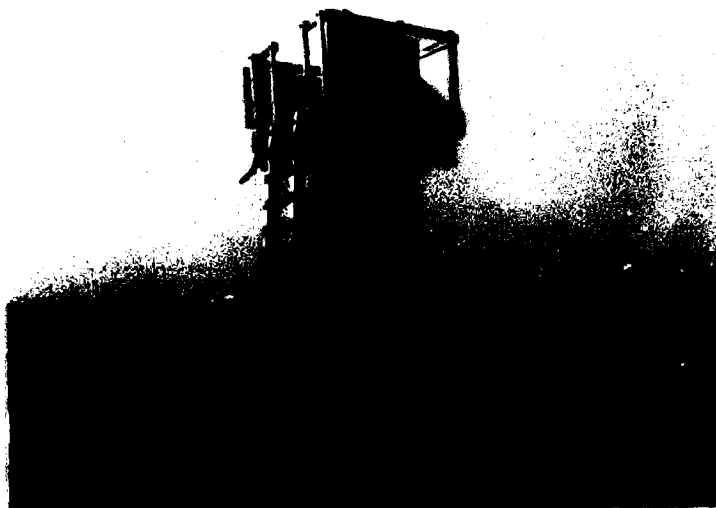
CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.  
NAVAL STATION CHARLESTON, S.C. FIG. NO.  
MSF DOWNTOWN  
**PIER AND BUILDING FACILITY 4.2-2**  
CONTRACT NO. N82477-83-D-0387



PHOTOGRAPH 4.2-3 Platform Dolphin 1.

PHOTOGRAPH 4.2-4 Platform Dolphin 2.





PHOTOGRAPH 4.2-5 Platform Dolphin 3.

PHOTOGRAPH 4.2-6 Platform Dolphin 4.





PHOTOGRAPH 4.2-7 Platform Dolphin 5.

U

A stray field garden consisting of 36 sensors, spaced at 5 ft centers in a six by six grid, is located along the east face of the pierhead. Refer to Figure 4.2-1 for a plan showing the location of the stray field garden.

Cable for the sensing fields run along the channel bottom, or are buried in the channel bottom, from platform dolphin to platform dolphin, and from a field in front of the pierhead to the building. In general, these cables are secured to the piles of the platform dolphins above water and hang free for at least part of their length. Excess cable lays on the channel bottom near each platform dolphin.

No live load design information was available for any of the structures.

#### 4.2.2 Observed Inspection Condition

The prestressed concrete piles of the access pier, building, equipment platform, finger pier and pierhead are in good condition. No evidence of significant damage or deterioration was found. Photographs 4.2-8 and 4.2-9 illustrate the typical condition of the concrete piles below and above water.

The timber fender system along the east side of the pierhead is in poor condition. At the waterline there is evidence of severe marine borer attack as shown in Photograph 4.2-10 and the tops of the piles have voids indicating fungi attack as shown in Photograph 4.2-11.

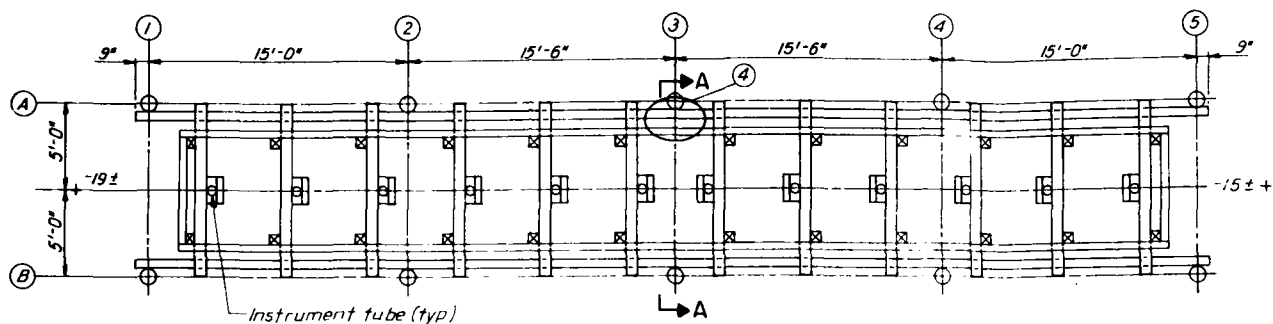
The timber mooring dolphin adjacent to the north end of the pierhead is in poor condition at the waterline, having lost approximately ten percent of its cross-sectional area as shown in Photograph 4.2-12

Platform Dolphin 1 is in fair condition. The prestressed concrete piles have some minor surface defects, but the distress does not extend to the reinforcing steel. The concrete cap of the piles is cracked and the lower east edge is broken off exposing reinforcement steel as shown in Photograph 4.2-3. The timber piles of the platform dolphin are in fair condition. They are in fair condition except at the waterline where they have lost approximately 20 percent of their cross-sectional area to marine borer damage.

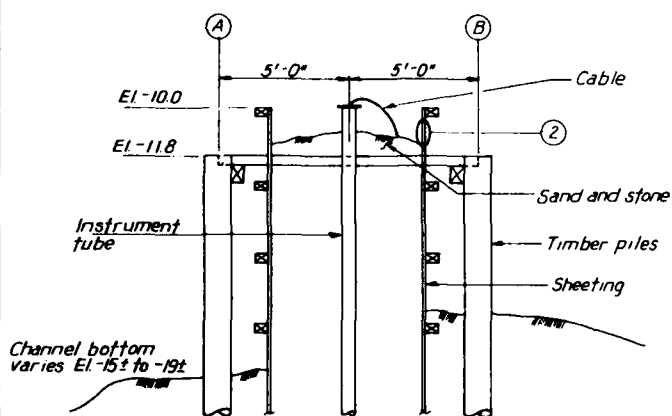
Platform Dolphins 2, 3, 4, and 5 are in fair condition. The timber piles are in good condition except at the waterline where they have experienced losses of cross-sectional area of 10 to 20 percent. The ends of the horizontal timber bracing are generally severely deteriorated from marine borer attack at each pile. Refer to Photographs 4.2-13, 4.2-14, and 4.2-15 for views of typical deterioration of the piles and bracing near the waterline.

Cores, borings, and ultrasonic inspection of the piles of the mooring dolphin and the five platform dolphins indicated

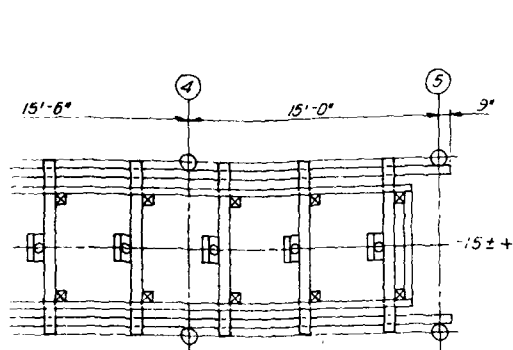




PLAN  
Scale: 1/4" = 1'-0"



SECTION A-A  
Scale: 3/8" = 1'-0"

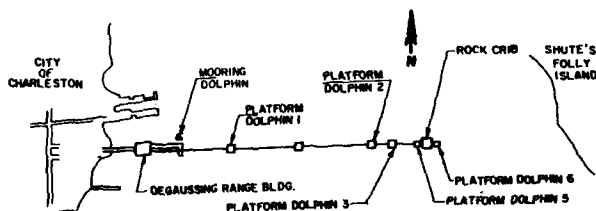


**GENERAL NOTES:**

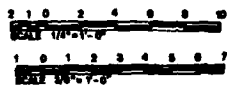
This drawing was developed in part from NAVFAC Drawing No. 1214589 and Y&D Drawing No. 916605.

**NOTES:**

1. All instrument tubes in good condition; vertical within  $\pm 1^\circ$ ; no tags on tubes.
2. Crib generally in good condition; minor holes in sheeting near east end of crib.
3. No undermining of crib.
4. Top timbers displaced  $6'' \pm$  at joint.



**KEY PLAN**  
NO SCALE



COLLINS ENGINEERS, INC.  
800 W. JACKSON  
CHICAGO, ILLINOIS

CHESAPEAKE DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
WASHINGTON, D.C.

NAVAL STATION CHARLESTON, S.C.  
MSF DOWNTOWN

**ROCK CRIB**

CONTRACT No. N82477-63-D-0387

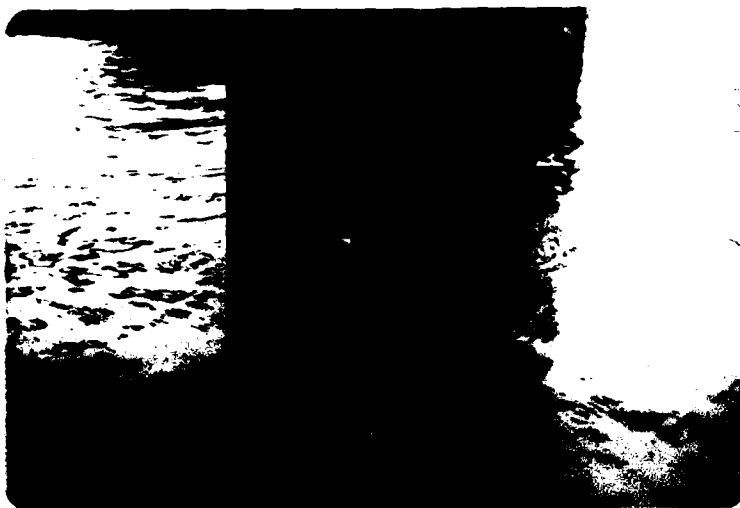
FIG. NO.  
**4.2-3**



PHOTOGRAPH 4.2-8 Typical Concrete Piles Above  
Water, South Side of Building,  
MSF Downtown.

PHOTOGRAPH 4.2-9 Typical Concrete Pile, Pile 19M,  
Elevation -8, MSF Downtown.

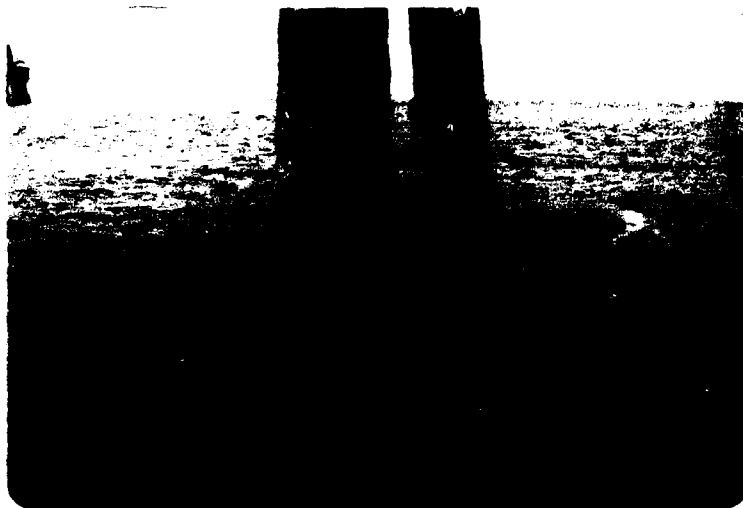




PHOTOGRAPH 4.2-10 Timber Fender Pile at 19M,  
MSF Downtown.

PHOTOGRAPH 4.2-11 Timber Fender Pile at 20M,  
MSF Downtown.





PHOTOGRAPH 4.2-12 Mooring Dolphin, MSF Downtown.

PHOTOGRAPH 4.2-13 Platform Dolphin 3 at Waterline, MSF Downtown.





PHOTOGRAPH 4.2-14 Platform Dolphin 4 at Waterline,  
MSF Downtown.

PHOTOGRAPH 4.2-15 Platform Dolphin 5 at Waterline,  
MSF Downtown.



These strengths were estimated from field data using the information contained in the Appendix. Generally, two readings were taken at right angles near Mean Low Water, at Elevation -5 and at Elevation -10.

Pile No	Diameter (Inches)	Wave Velocity Range (Ft per second)	Estimated Dry Crushing Strength (Psi)
Platform Dolphin 2:			
A	11 5/8	3500 to 4100	3200
B	13 1/8	3700 to 3900	3200
C	11 9/16	3800 to 3900	3200
D	13 3/8	4200 to 4500	3700
Platform Dolphin 3:			
A	12 15/16	4000 to 5100	3800
B	12 3/16	4000 to 4300	3600
C	13 15/16	4500 to 4800	4000
D	13 5/16	4000	3400
Platform Dolphin 4:			
A	12 1/16 to 13	4800 to 5700	4400
B	12 5/8	4500	3600
C	12 3/8	5300	4400
D	12 3/8	3300 to 4100	2500
Platform Dolphin 5:			
A	12 1/4	4900	4200
B	13 5/8	4200 to 4600	3800
C	13 5/8	5200	4400
D	13 1/4	4800 to 5600	4400
Mooring Dolphin:			
West	10 1/2	4200 to 5100	4000

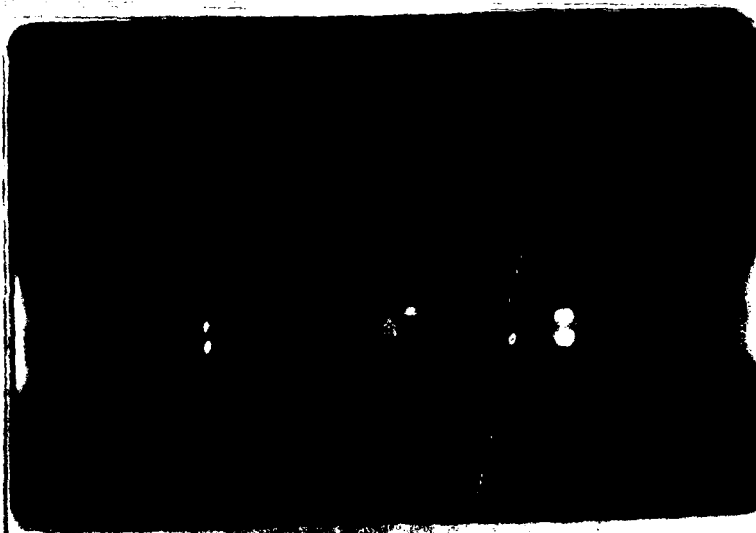
Platform Dolphin 1 was too severely deteriorated near the waterline to obtain meaningful readings.

The timber crib that contains the sensor tubes of the shallow range is in fair condition. The crib was found to all be intact, and the sensor tubes were all adequately supported. All tubes were measured with an inclinometer and found to be within one degree of vertical. No identification tags were found on any of the tubes. Refer to Photograph 4.2-16 for a view of one of the sensor tubes. The timber sheeting on the east half has a number of holes and spaces between the sheets near the top of the crib, but there does not appear to be any loss of fill material at this time. Refer to Photographs 4.2-17 and 4.2-18 for views of two of the holes. The top timbers on the north side of the crib are displaced approximately 6 inches at a construction joint between the original and rebuilt portion of the crib. The fill within the crib was generally between 1 to 2 feet below the top of the crib. No evidence of undermining was found around the outside of the crib.

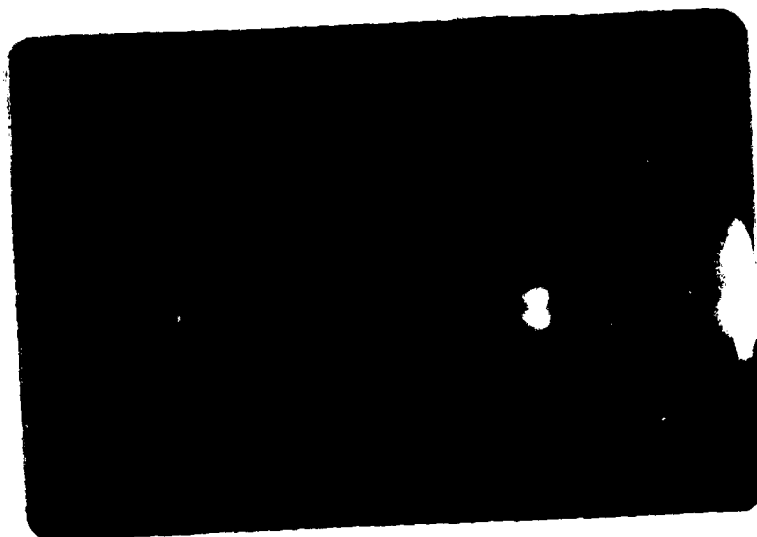


PHOTOGRAPH 4.2-16 Platform Dolphin 4, Pile B,  
Elevation -8, MSF Downtown.

PHOTOGRAPH 4.2-17 Instrument Tube, Rock Crib,  
MSF Downtown.

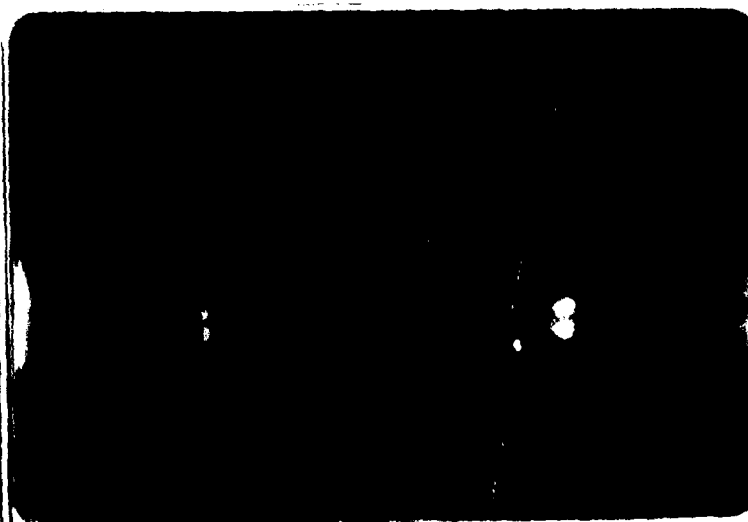






PHOTOGRAPH 4.2-18 Hole in North Face Rock Crib,  
Near Top, Near Pile 3A,  
MSF Downtown.

PHOTOGRAPH 4.2-19 Hole in North Face of Rock Crib  
Near Top, Near Pile 4A,  
MSF Downtown.



the original and rebuilt portion of the crib. The fill within the crib was generally between 1 to 2 feet below the top of the crib. No evidence of undermining was found around the outside of the crib.

The medium range sensor tubes could not be located by the divers. The divers followed the sensor tube cable runs from the adjacent platform dolphins until the cables became buried in the channel bottom. Attempts to locate the tubes beyond the point where the cables entered the bottom were unsuccessful because of the strong river current. Correlation of the sounding data with the design drawings, as indicated on Figure 4.2-1 indicates that the sensor tubes and channel bottom are in approximately the same relationship as originally placed.

The sensor instruments immediately east of the pierhead were also found to be buried in the channel bottom. The divers followed the cable runs for these devices from the pierhead until they became buried in the channel bottom, and searched the area adjacent to the pierhead for exposed instrument tubes. No tubes were found, and there was no evidence of scour in the area.

In general, the area of channel bottom in front of the pierhead and at the base of each platform dolphin is a maze of slack twisted cable runs.

#### 4.2.3 Structural Condition Assessment

The concrete piles of the access pier, building, equipment platform, finger pier, and pierhead are in good condition. No significant structural damage or deterioration was observed.

The timber pile fender system along the east side of the pierhead and the mooring dolphin adjacent to the north end of the pierhead are in poor condition, and should be replaced.

The concrete piles of Platform Dolphin 1 are in good condition. The cracking of the pile cap, while it has not reduced the structural capacity of the platform at this time, does provide an avenue which may allow moisture and oxygen to reach the reinforcing steel. This could result in corrosion of the steel and eventual reduction in the pile cap capacity.

The timber piles of all platform dolphins exhibit significant deterioration in the tidal zone due to marine borer attack. The portions of the piles below the tidal zone are in good condition. Because the loads on the deteriorated portions of the piles are relatively small, the ability of the structures to perform their intended function has not been impaired at this time. If the deterioration at the waterline is not repaired in the near future, however, it can be expected that the deterioration will continue and the ability of the structures to carry normal loads will be reduced.

The rock-filled crib is in fair condition. The few

holes in the sheeting on the sides of the crib could allow some of the rock and fill to be displaced. The holes should be sealed to prevent loss of the fill. The structure as a whole, however, appears to be structurally stable and able to withstand the forces of the river acting on it.

The sensor tubes appear to be adequately supported and no remedial measures are indicated.

#### 4.2.4 Recommendations

It is recommended that the timber fender system on the east face of the pierhead and the mooring dolphin, if it is required for operational reasons, be replaced.

It is recommended that the cracked and broken pile cap of Platform Dolphin 1 be restored. All loose and cracked concrete should be removed and exposed reinforcing steel should be cleaned to bright metal before new concrete is placed. If the cross-sectional area of the existing reinforcing steel has been reduced by more than 10 percent, additional reinforcing steel should be added.

It is recommended that all timber piles of Platform Dolphins 1 through 5 be repaired by jacketing with concrete from approximately Mean High Water to Elevation -5. The horizontal bracing should also be replaced at the same time and be placed below the tidal zone.

It is also recommended that the holes in the sheeting of the timber crib be repaired by placing grout-filled fabric bags within the crib against the defective timber.

The estimated cost of the work described above is \$180,000. Refer to the Appendix (A-1) for a detailed cost estimate.

It is further recommended that these facilities be inspected at three year intervals until the repairs are accomplished; be inspected after the repairs are accomplished; and be reinspected at six year intervals thereafter.

REPAIR COST ESTIMATES

PIER YANKEE

Repair Cracks and Spalls on 3 Piles	
A. Clean piles:	\$3,000
B. Apply epoxy grout	5,000
C. Mobilization	<u>4,000</u>
Total for Pier Yankee	\$12,000

Contractor's Repairs:	
A. Patch 2 piles and 2 pile caps with epoxy grout	\$ 1,000
B. Replace horizontal timber brace	\$ 1,000

MAGNETIC SILENCING FACILITY - DOWNTOWN

1. Fendering System:	
A. Remove existing fendering system	\$10,000
B. Drive piles -250 L.F. @ \$50	12,500
C. Install new wales & chocks	20,000
D. Mobilization	<u>10,000</u>

Subtotal	\$50,000
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2. Rock Crib:	
A. Fill and place grout bags with divers - 5 days @ \$4,000	\$20,000
B. Mobilization	<u>5,000</u>

Subtotal	\$25,000
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3. Platform Dolphins:	
A. Repair concrete cap	\$10,000
B. Clean & jacket piles with concrete 20 @ \$2,000	40,000
C. Replace bracing 5 platforms @ \$5,000	25,000
D. Mobilization	<u>5,000</u>

Subtotal	\$80,000
----------	----------

4. Replace Mooring Dolphin:	
A. Pull old piles; drive new piles 1 day @ \$15,000	\$15,000
B. Mobilization	<u>10,000</u>

Subtotal	\$25,000
----------	----------

Total for MSF-Downtown	\$180,000
------------------------	-----------

#### METHODOLOGY FOR ULTRASONIC TESTING OF TIMBER PILES UNDERWATER

This investigation included inspection of submerged timber pilings using a nondestructive testing technique for determining the in-place residual strength of the timber piling. The testing technique is an ultrasonic wave propagation method developed at the University of Maryland, Department of Civil Engineering under grants from the U.S. Department of Transportation, Federal Highway Administration and the Maryland State Highway Administration. The methodology is described in an Interim Report, dated June, 1982, Report No. FHWA/MD-82/10, titled "Safety and Soundness of Submerged Timber Bridge Piling".

The methodology was developed following the failure of a timber supported bridge in Maryland. An inspection of the timber piles of that bridge prior to the failure had indicated that the timber was relatively sound, but later laboratory tests indicated that there had been a substantial reduction in the strength of the pilings due to damage to the wood microstructure that caused loss of strength and density. The technique also can be used to determine the loss of strength due to internal marine borers, such as teredo, which is not visible from the outside.

The testing equipment consists of a "V-Meter" manufactured by James Instruments, Inc., a portable ultrasonic nondestructive digital tester and two transducers, each mounted in a stainless steel case, with a frequency of 54 KHz. It provides a means of generating and transmitting pulses of ultrasonic sound through the wood pile material, and electronically measuring the time of transmission of the sound from the face of the transmitter to that of the receiver.

From tests made on a number of timber pile samples, the study developed empirical formulas, and charts based on those formulas, to estimate the residual strength of timber piles. The following ten pages are reproduced from the Interim Report described above to illustrate the computational procedures. The empirical formulas were developed from a band of data, and engineering judgement must be used when evaluating a particular structure to select average strength values consistent with the engineer's confidence in the data obtained. If, for example, the wave velocities obtained are grouped closely together, an arithmetic average might be appropriate; while, if the values are widely dispersed, the selection of a lower value might be more appropriate. It should also be recognized that there are other limitations affecting the applicability of this method, and the reader is referred to the Interim Report for a discussion of those limitations.

## 6.6 Limitations

### 6.6.1 Measurements

A major factor which could limit the reliability of the test is the accuracy of the measurements. The parameters normally measured as part of the test and the average estimated accuracy of these measurements are transit time and path length.

These parameters can be measured with sufficient accuracy provided adequate care and precaution are exercised when conducting the tests.

The most essential parameter which is difficult to measure accurately is the path length (distance) between the interface of the transducers. These measurements are obtained using the built-in linear variable differential transducer (LVDT), as described in Section 6.2. While this procedure may improve the accuracy of estimated path length appreciably, the introduction of the conversion factor requires prior investigation. The correction (or conversion) factor needs to be constantly estimated for the D.C. voltage source used.

### 6.6.2 Computation

Another major factor affecting the results and limitations of the in-situ test is the applicability of the computational theory. One limitation of the computational theory is the assumption that the wood is an isotropic-orthotropic body while actually, it is a body possessing cylindrical anisotropism. The validity of the assumption is affected by the internal grain disturbances.

Another limitation of the computational theory is an assumed perfect coupling between the transducers and the pile. Inadequate coupling will result in a lower velocity, thus an underestimation of the dynamic modulus. However, the field coupling which is attained when the multimeter readouts remain constant tend to minimize this possibility.

Another limitation of the computational theory is the margin of error introduced by density variations. Each wood species used as a piling material has a

variation in values of densities. These densities are also functions of other factors, such as water content and grain distribution. As it is difficult to determine the density at each section along the entire pile, an average estimated value obtained from laboratory testing or taken from publications would influence the dynamic modulus and residual crushing strength computed at each test location.

#### 6.6.3 Effect of Equipment Set-up

The procedure for the testing assumes that the underwater gear and the sensing assemblage are in perfect horizontality and remain unaltered during the scanning of the pile. A departure from this condition affects the computed velocity and consequently, the interpretation of the results. The path length measurement obtained by an inclination of the equipment would vary from that obtained normally. Also, imperfect transducer/pile contact would result. The error due to this factor could be minimized by careful field testing.

Another procedural limitation is the assumption that fouling or debris would not accumulate enough on the pile surface. If this condition is altered at the test site due to insufficient water movement necessary to prevent this accumulation, the computed velocity and dynamic modulus would result in misinterpretation of the results.

#### 6.7 Data Analysis

Having determined the pile diameter ( $D_i$ ) and the time ( $T_i$ ), the basic information desired from the data obtained is given by:

##### 6.7.1 Velocity Normal to Grain $V_N$

$$V_N = \frac{D_i}{T_i} \times \frac{1}{12} \text{ (ft/sec)} \quad (6.1)$$

where

- $V_N$  = wave propagation velocity normal to grain, in feet per sec
- $D_i$  = path length (effective) at section
- $D_i = D - M_1 V_1 - M_2 V_2$  (6.2)
- $M_1$  and  $M_2$  = voltage conversion factors for sensors 1 and 2 respectively
- $V_1$  and  $V_2$  = voltage changes in volt for sensors 1 and 2 respectively
- $T_i$  = transit time measurement in microsec
- $D$  = reference point's path length

From the data obtained in this work, it was found that for a new pile in excellent condition the wave velocity  $V_N$  was 5880 ft/sec or higher, while for a pile in good condition, the velocity was between 5170 to 5880 ft/sec.

For old piles free from decay, old piles with small decayed areas and old piles with large decayed areas, the velocity of waves were 4560 to 5170 ft/sec, 3500 to 4560 ft/sec, and 1850 to 3500 ft/sec, respectively.

#### 6.7.2 Velocity Parallel to Grain $V_L$

The relationships developed through the experimental work are shown in Fig. 6.11a and 6.11b.

New piles

$$V_L = a_1 + b_1 \cdot V_N \text{ (ft/sec)} \quad (6.3.a)$$

Old piles free from decay

$$V_L = \bar{a}_1 V_N^{b_1} \text{ (ft/sec)} \quad (6.3.b)$$

where

$V_L$  = wave propagation velocity parallel to grain, in feet per sec

$a_1, b_1$  = constants of the linear regression, and

$\bar{a}_1, b_1$  = constants for non-linear relationship

#### 6.7.3 Material Density $\rho$

The material density of the old pile sections is correlated to the wave velocity normal to grain ( $V_N$ ) Fig. 6-12, in a general non-linear formula as

$$V_N = a_2 R^{b_2} \quad (6.4)$$

where

$a_2, b_2$  = constants that were determined from the data of sections cut from old piles obtained from different bridges, and

$R$  = density ratio, which is the ratio between the density of an old section to the density of a new section

The information about the density of the pile material when they were new, together with the above formula, can be a good estimation of the density of old piles.

#### 6.7.4 Dynamic Modulus

Having determined the wave velocity ( $V_L$ ) for each section at each depth, the dynamic modulus in longitudinal direction  $E_L$ , at each depth is computed by

$$E_L = \frac{V_L^2 \rho}{144 \times g} \text{ in psi} \quad (6.5)$$



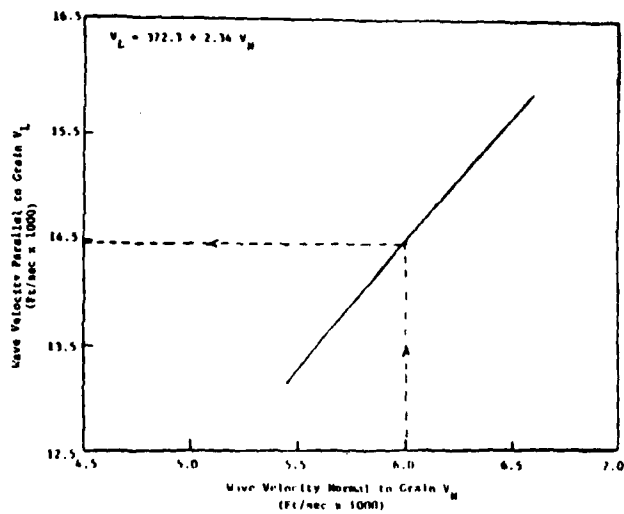


Figure 6-11.a Wave Velocity Parallel to Grain and Wave Velocity Normal to Grain for Treated Pine (Recommended For New Treated Pine)

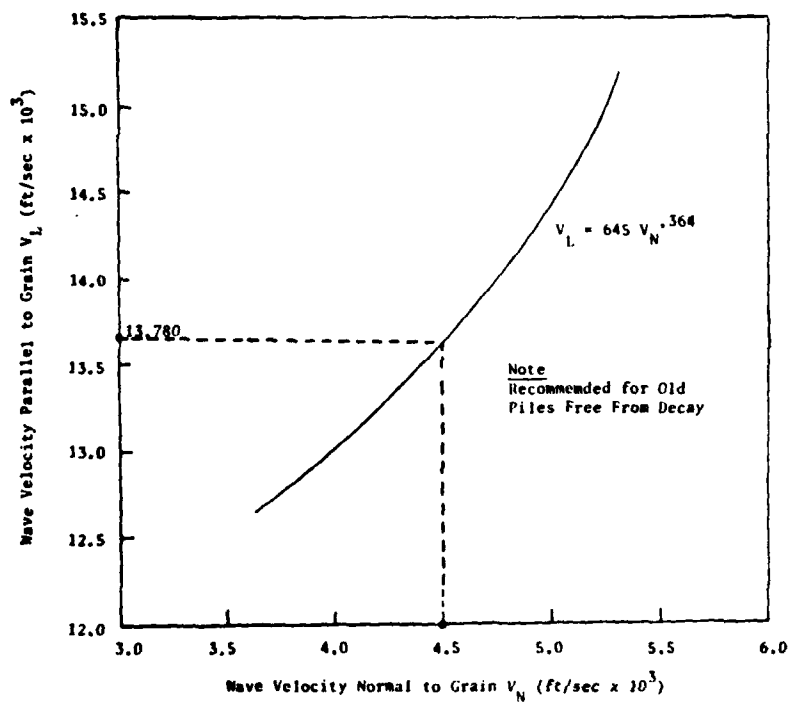


Figure 6-11.b Wave Velocity Parallel to Grain  $V_L$  and Wave Velocity Normal to Grain  $V_N$  For Old Piles Free From Decay

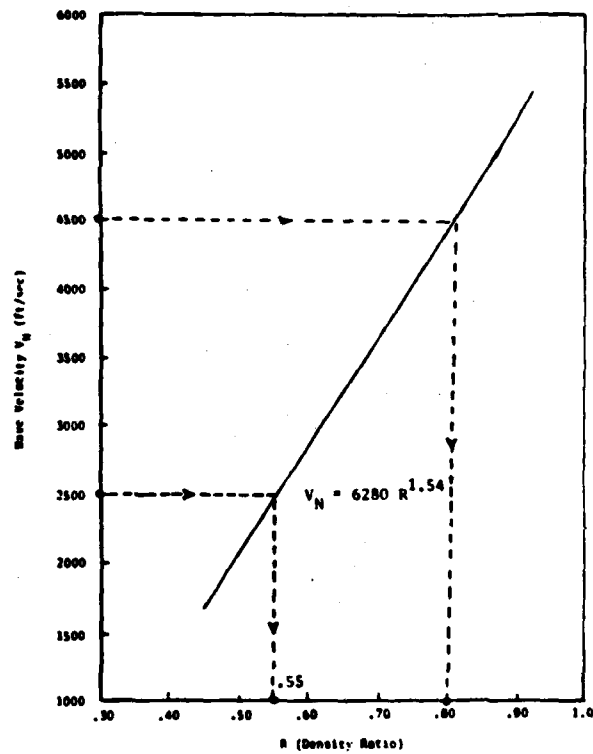


Figure 6.12 Wave Velocity and Density Ratio for Old Piles Obtained from Different Bridges

where

$V_L$  = velocity parallel to grain

$\rho$  = density of wood sections in lb/cu ft

$g$  = gravitational acceleration constant (ft/sec<sup>2</sup>)

#### 6.7.5 Crushing Strength ( $\sigma_{cr}$ )

The evaluation of the crushing strength of the pile sections can be found from one of the following equations:

- a. Single variable (Figs. 6.13a, 6.13b)

$$E_L = a_3 + b_3 \cdot \sigma_{cr} \quad (6.6)$$

- b. Multi-variable (Figs. 6.14a, 6.14b and 6.14c)

$$\sigma_{cr} = a_4 V_N + b_4 \cdot \quad (6.7)$$

where

$a_3$ ,  $b_3$ ,  $a_4$  and  $b_4$  are constants

It is recommended to use Equation (6.6) when the piles are either new or old but free from decayed areas. The use of the multi-variable equation gives an estimation of the crushing strength for piles either new, old, or with decayed areas.

#### 6.7.6 Sample Calculations

The following cases are presented to demonstrate how the data can be reduced and the parameters required obtained.

##### Case 1. New Treated Pine Pile

Assume the pile diameter  $D = 12.0$  inches, the average time reading  $T$  using the V-meter is 166  $\mu$  sec and the material density  $\rho = 41$  lb/ft<sup>3</sup>. The average wave velocity normal to grain ( $V_N$ )

$$= \frac{D}{T} = \frac{12/12}{166 \times 10^{-6}} = 6000 \text{ ft/sec}$$

##### Method (1)

1. Wave velocity parallel to grain  $V_L$  using Fig. (6.11a)  
= 14400 ft/sec

2. Dynamic modulus parallel to grain  $E_L$

$$= \frac{\rho V_L^2}{144 \times 32} \times \frac{1}{1000}$$

$$= \frac{44(14400)}{144 \times 32} \times \frac{1}{1000} = 1980 \text{ ksi}$$

3. Crushing Strength ( $\sigma_{cr}$ ), using Fig. (6.13a) = 5100 psi

Method (2)

1. Crushing Strength ( $\sigma_{cr}$ ), using Fig. (6.14a) = 5025 psi

Case 2. Old Pine Pile, Free From Decay

Assume the pile diameter  $D = 12.0$  inches, the average time reading  $T$  using the V-meter is  $222.0 \mu \text{ sec}$ . The material density of the pile when it is new =  $44 \text{ lb/ft}^3$ . The average wave velocity normal to grain ( $V_N$ )

$$= \frac{D}{T} = \frac{12/12}{222 \times 10^{-6}} = 4500 \text{ ft/sec}$$

Method (1)

1. Wave velocity parallel to grain  $V_L$  using Fig. (6.11.b)

$$= 13780 \text{ ft/sec}$$

2. Material density ratio  $R$  using (Fig. 6.12)

$$R = .805$$

then

$$\begin{aligned} \rho_{old} &= \rho_{new} \times R \\ &= 44.0 \times .805 \\ &= 35.2 \text{ lb/ft}^3 \end{aligned}$$

3. Dynamic modulus parallel to grain ( $E_L$ )

$$\begin{aligned} &= \frac{\rho V_L^2}{144 \times 32} \times \frac{1}{1000} \\ &= \frac{35.2(13780)^2}{32 \times 144} \times \frac{1}{1000} \\ &= 1445 \text{ ksi} \end{aligned}$$

4. Crushing strength ( $\sigma_{cr}$ ), using Fig. (6.13.b) = 2870 psi

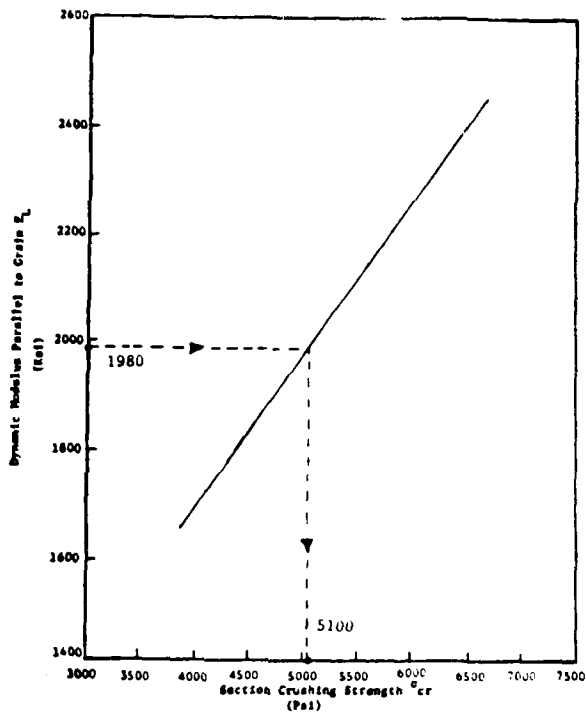


Figure 6-13.a Dynamic Modulus and Crushing Strength for Treated Pine  
(Recommended for New Pile)

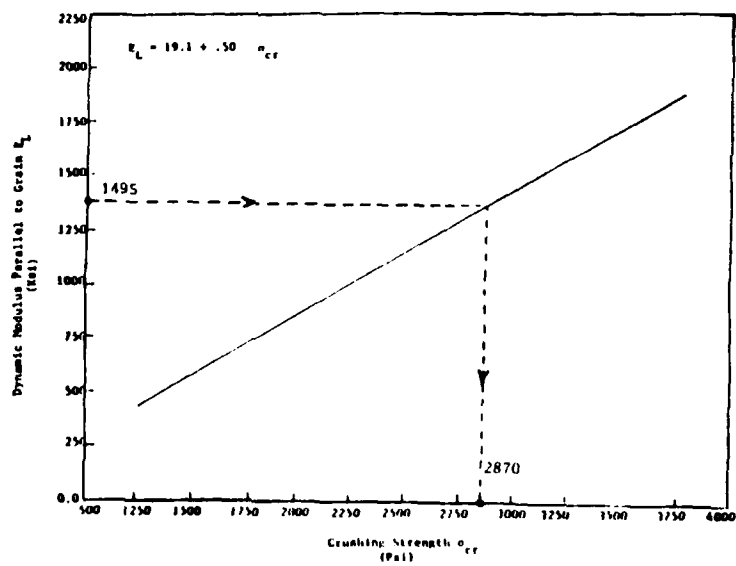


Figure 6-13.b Dynamic Modulus and Crushing Strength for Old Sections  
From Piles Obtained From Different Bridges

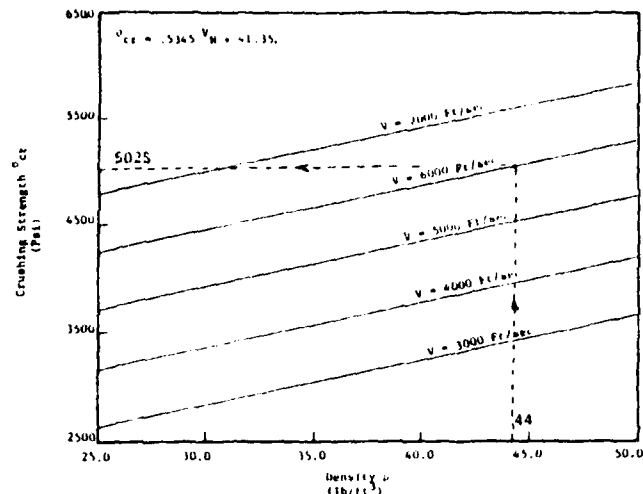


Figure 6-14.a Crushing Strength and Density for New Treated Sections of Pine

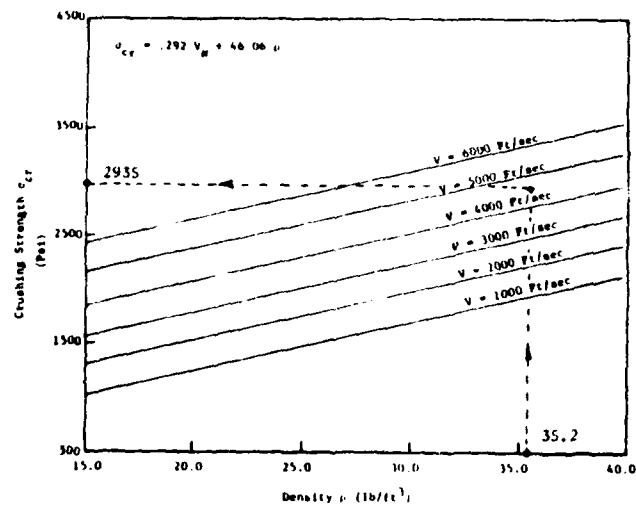


Figure 6-14.b Crushing Strength and Density for Model Developed From Data Of Sections Obtained From Old Piles From Different Bridges

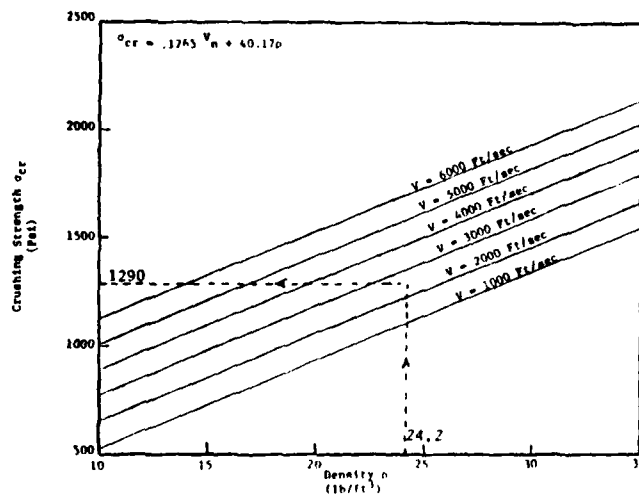


Figure 6-14.c Crushing Strength and Density for Sections Obtained From Piles on Bridge No. 9015 on Mh. Rt. 392 over Marshhope Creek (Recommended for Decayed Section)

#### BOATHOUSE PILE STRENGTH COMPUTATIONS AND SAMPLE PILE CORRELATION

A sample pile, driven at the same time as the Boat House piles and believed to be representative of the conditions found at the Boat House, was cut into sections to obtain specimens of the timber at approximately 5 ft intervals from Elevation +5 to the channel bottom. The pile was determined to be southern pine. Refer to Photograph A-1 and A-2 for views of the pile. The sections of this pile, approximately 9 inches thick, were tested ultrasonically and cut into specimens 1 in. x 1 in. x 4 in. as shown in Photograph A-3. These specimens were tested in accordance with the ASTM requirements for determining the crushing strength of timber specimens as summarized below:

<u>Elevation</u>	<u>Number of Specimens</u>	<u>Average Wet Strength</u>	<u>Average Dry Strength</u>
+5	8	3168 psi	4752 psi
0	8	3316 psi	4974 psi
-10	8	2970 psi	4455 psi
-15	7	2974 psi	4461 psi
-20	8	2492 psi	3738 psi

The ultrasonic wave pulse measurements of the piles tested in-situ corresponded to an average dry strength of approximately 4400 psi. Refer to the examples of the computation of the approximate dry strength from the wave pulse velocity measurements on Page A-18. The results of the ultrasonic testing and compression testing showed a good correlation.

Also, in order to verify that if teredo damage had been present it would have been detected, a number of holes were drilled in the sample pile shown in Photograph A-4 to simulate internal marine borer attack, and the piles were tested ultrasonically. As shown on Photograph A-5, holes were first drilled along one axis, 1-1. The ultrasonic pulse wave measurements were influenced along that axis, but not in the three other direction marked on the sample. Additional holes were then randomly drilled in the sample as shown in Photographs A-6 and A-7. When the number of holes produced a loss of area of about 17 percent, the pulse velocity was reduced by about one-half. In some directions no readings could be obtained because the sound energy was so severely attenuated by the holes that it could not be detected by the receiving transducer. This is because when an ultrasonic wave travels through homogeneous material with little loss, but when intercepted by discontinuities, attenuation of the travelling plane waves occurs due to reflection, refraction, diffraction and scattering. The amount of attenuation is a function of the type of sonic equipment used, and the location and size of internal voids, but this test indicated that this type of damage can be detected using the sonic testing method described above.





PHOTOGRAPH A-1 Cut Sample Pile at Pier Yankee.

PHOTOGRAPH A-2 Sections Cut from Sample Pile.

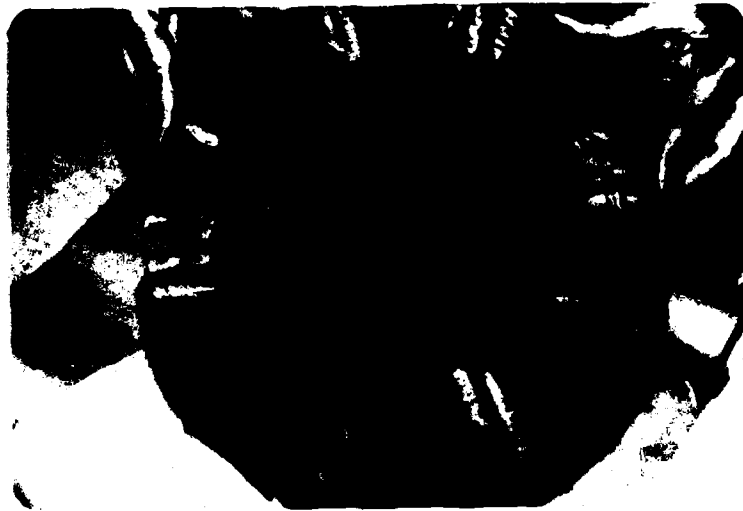




PHOTOGRAPH A-3    Sections Cut into Specimens  
                                 (1 in. x 1 in. x 1 in.) for  
                                 Compression Testing.

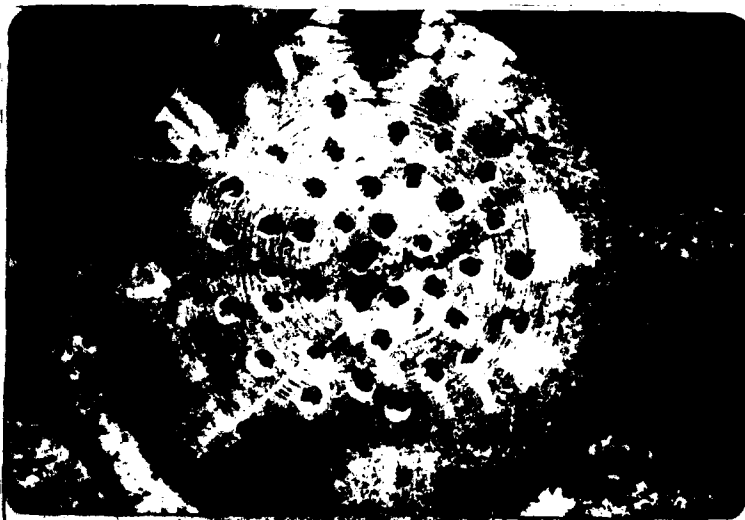
PHOTOGRAPH A-4    Section Used in Testing.





PHOTOGRAPH A-5    Section with Holes in  
Direction 1-1.

PHOTOGRAPH A-6    Section with Holes Randomly  
Located.





PHOTOGRAPH A-7 Section with Additional Holes  
Randomly Located.

In estimating the residual strength of the piles for this project, because the wave velocity measurements, the borings, and the visual examination of the sample pile indicated that the timber was in relatively good condition with no evidence of internal decay, computations were made using the formulas for new treated piles. When a range of wave velocity measurements were found for a particular pile, the crushing strength was estimated for the extremes of the range, and an approximate, rounded, average was selected.

#### Sample Calculations

Pile No	Diameter (Inches)	$V_N$ (fps)	$e$ (pcf)	$\sigma_{cr}$ (psi)	Average $\sigma_{cr}$ (psi)	Fa (psi)
5D	12.94	5100	40	4357	4600	1150
		5900	40	4781		
5F	14.81	4600	40	4092	4400	1100
		5900	40	4781		
3D	12.94	4400	40	3986	4000	1000
		5100	40	4357		

Where:

$V_N$  = Wave velocity normal to grain (measured in field)

$e$  = Density of timber (Approximately 40 pcf)

$\sigma_{cr}$  = Crushing strength of timber (Figure 6-14.a)

$$\sigma_{cr} = .53 V_N + 41.35e$$

Fa = Allowable working stress in timber assuming a factor of safety of 4.0

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